Memo

To: Intel Corporation

From: Tourbillon Group, Senior Design Team (Howard University)

CC: Dr. Trimble, On-Campus Advisor (Howard University)

Date: 12/9/2009

Re: Project Proposal

In response to Intel's need for a standard method to evaluate the performance of WiMAX networks and devices, as a component of the Intel Design Challenge Team at Howard University, we have devised an approach to establish such a method. The attached documentation is a proposal concerning the previously mentioned approach that further explains our purpose.

Included within this documentation is the following:

- Introduction
- Problem Definition
- Current Status of Art
- Engineering Approaches
- Tasks and Deliverables
- Project Management
- Conclusions

In our research, discussions, and collaboration with the Intel Design Challenge Team at-large, we have been able to conceptualize and understand the subject matter to a degree. Being given the opportunity to establish a test system in this manner and scale allows for an approach to design that we would not normally experience, and are grateful for the opportunity.

We, as the Tourbillon Group, hope that the project proposal is to your satisfaction, and we look forward to your feedback on its contents soon.

Senior Design I

Intel Design Challenge – WiMAX

Project Proposal

Tourbillion Group:

Jonathan Charlery

Cesar Gomes

Brandon Montgomery

Abeeku Paulos

Signature of Approval _____

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Introduction

Intel advocates the advancement of education and the provision of opportunities to students in the 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 State 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, network optimization, coverage area tower placement, and consistency in their products that leverage WiMAX technology.

CUSTOMER NEED

Intel expressed the need to determine how a WiMAX-enabled network and/or device would perform under varying conditions and environments (i.e. urban, suburban, coverage dense, and coverage sparse environments).

MAIN PROBLEMS

In considering Intel's need to determine WiMAX performance, the main problems with accommodating such a need are as follows:

- Developing a standard method to analyze a system's performance out of numerous available methods in industry will be difficult.

OBJECTIVE(S)

The objectives of our design project with respect to the need(s) defined above are as follows:

- Analyze the needs of the industry in order to formulate a proper and effective solution.
- Establish a Problem Definition that focuses on the need.
- Research current methods, practices, and systems of current solutions to the defined problem.
- Formulate solution based on previous objectives.
- Establish milestones and a timeline that will help as a guide throughout the process.
- Create working system to demonstrate the solution by designated time.

GOALS & SCOPE

The major goals of our design team are as follows:

- Attain working knowledge of WiMAX.
- Learn engineering testing methodology with respect to a system's performance.
- Establish a plan of action to assess the industry-defined problem.
- Implement said plan of action and attain desired results.
- Formulate a testing methodology based on the attained results.
- Refine the testing methodology.
- Create working system that implements testing methodology for final presentation.

The scope of our design team is defined by the following:

- The system to be formulated, developed, and delivered is a testing system of WiMAX networks and/or devices, not a WiMAX network and/or device itself.
- We are constrained to formulate, develop, test, and deliver a system that represents the solution that we devise by the ECE Day in April 2010.

PROPOSAL CONTENT

The content of the remainder of this documentation is as follows:

1. Problem Definition
2. Current Status of Art
3. Engineering Approaches
4. Tasks and Deliverables
5. Project Management
6. Conclusions

PROBLEM DEFINITION

In considering Intel's need, we have refined the problem definition to the following statement:

How should we best formulate and deploy a test method to evaluate emerging WiMAX consumer 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.

DESIGN REQUIREMENTS

The following are the design requirements that we established to fulfill the previously mentioned purpose (note: See the appendix for the Design Requirements spreadsheet):

Overall Performance

- To evaluate and determine the performance of WiMAX-enabled networks and/or devices by April 2010.

Performance

- Determine basic coverage and user level performance of existing Wireless Broadband Services in the Baltimore, MD area.
- Determine the capability of the Wireless Broadband to support various applications in a mobile environment by leveraging the Baltimore Light Rail (i.e. testing handoff)
- Understand indoor penetration of Wireless Broadband signals in an urban landscape

Safety

WiMAX itself is held to the same safety regulations as each form of wireless communication implemented to date. Most notably, the standards set by IEEE, ANSI, FCC, and the like. However, there are no true safety standards set or even really necessary with respect to testing WiMAX devices.

Compliance

The IEEE 802.16 standard, and all its revisions and additions, set the parameters that WiMAX devices and the testing of said devices must comply with.

Interfaces

- Intel FIDO software to retrieve Key Performance Indicators (i.e. RSSI, CINR, etc);
- Five (5) laptops with embedded WiMAX chipset for testing and analysis
- Additional interfaces to be developed.

Energy, Power, and Environment

- Considering the travel, power inverters, and five (5) laptops in use, the current energy efficiency of the testing process as is can be considered abysmal.
- This will be rectified with further analysis in order to minimize the impact on energy/power consumption, as well as environmental affects.

Lifespan

- The standard method for testing shall evolve with the IEEE 802.16 standard.

Size, Weight, Maintenance

- Because there we are in the beginning stages, there are no known parameters for size and weight.
- When regarding maintenance, the current method is constrained to maintenance of the current laptops to be used, as well as backing up and maintaining the data to be recovered from the testing.

Timeline and Schedule

- See Engineering Approaches

Current Status of Art

In evaluating testing methods, we must consider the current methods, devices, and applications being used in the industry today. The following summarizes the search and research results of the existing products or technologies that were developed as solutions to needs similar to, if not the same as Intel's need. Included is a description of their advantages and disadvantages in the perspective of the design requirements of the project. Also, we identify the main technological point that serves as the reason why the proposed project is important and solves the problem.

HARDWARE ONLY

Bit Error Rate Tester (BERT Scope) analyzers serve to analyze the transmission behavior of data and telecommunication systems at bit level. Bit errors can be determined quantitatively and may be evaluated with regard to quality aspects. Even the origin of an error can be localized. The bit pattern received is compared against a known pattern in order to identify errors .for both synchronous and asynchronous devices.

- Advantage
  - Tests transmissions at the bit level for any possible error
  - Eye-diagram measurements help to quickly assess measurement results.
- Disadvantage
  - Additional cost of system for testing
  - Limited mobility of system

Radio Frequency Vector Signal/Spectrum Analyzers provide extensive and unique capabilities for signal analysis of devices that use existing wireless standards and new wide bandwidth, complex modulation, and high throughput wireless communication standards.

- Advantage
  - High quality measurements not compromised by high speed testing
  - Test Multiple Input Multiple Output devices with low instrument uncertainty
- Disadvantage
  - Collects raw, unprocessed signal information that is at a deeper level than the project entails
  - Additional cost of system for testing

SOFTWARE WITH ADDITIONAL HARDWARE

A **Network and Service Analyzer** (NSA) is a suite of fully-automated software applications for troubleshooting and optimization of mobile networks and services. NSA allows multiple users to trace subscribers' calls both in real time and offline as they travel across the network over multiple interfaces and over several network elements, such as control plane and user plane analysis.

- Advantage
  - Multi-Interface call/session trace enables rapid identification of issues down to root cause to allow you to focus on fixing issues, not finding them.
  - Identification of network problems and service quality degradation, from the symptom down to the root cause
- Disadvantage
  - Designed to support the K18 and K15 platforms (Additional components)
  - Cost of acquirement

Real-Time Spectrum Analyzer (Software) provides spectrum and modulation measurements on Orthogonal frequency-division multiplexing (OFDM) and Orthogonal frequency-division multiple access (OFDMA) signals in accordance with standard IEEE 802.16-2004 (fixed) and IEEE 802.16e (mobile) WiMAX standards. The software application programming interface allows users to automate measurements to characterize system and device performance.

- Advantage
  - Automated measurement applications
  - Identification of network problems and service quality degradation, from the symptom down to the root cause
- Disadvantage
  - Needs additional hardware and system integration

- Cost of acquirement

Intel's FIDO Software is an inter-virtual machine communication mechanism that leverages the inherent hardware applications between the software components in an appliance to achieve high performance. This is an application provided for our use.

- Advantage
  - Records performance of device's with Intel's embedded WiMAX chipset
  - Completely Digital Approach
  - No Additional Hardware Required
  - Interface is within the device to be tested
- Disadvantage
  - In house (Intel) software with little documentation

Engineering Approaches

The testing will be executed by teams of two, who will utilize five (5) WiMAX enabled, fully configured laptops, which will be provided by Intel. Each laptop will have the FIDO software that records the data transfer performance of the laptops. We will also be provided with 2terabyte (2TB) hard drives for backing up the data after each test period.

INITIAL SOLUTION

The process to formulate and execute the solution shall be implemented in two phases. The first phase consists of practical testing on-site followed by statistical analysis. The testing will begin on the first Friday of November. The testing breaks down in the following manner:

- Designated Testing Sites in Baltimore, MD
  - Baltimore-Washington International Airport
  - Towson
  - Morgan State University
  - Johns Hopkins University
- Choose Location to test around/in (buildings of varying types)
- 10 minutes outdoor testing (5 minutes uplink, 5 minutes downlink with FIDO outside of chosen site)
  - Establishes location with GPS
  - Document location

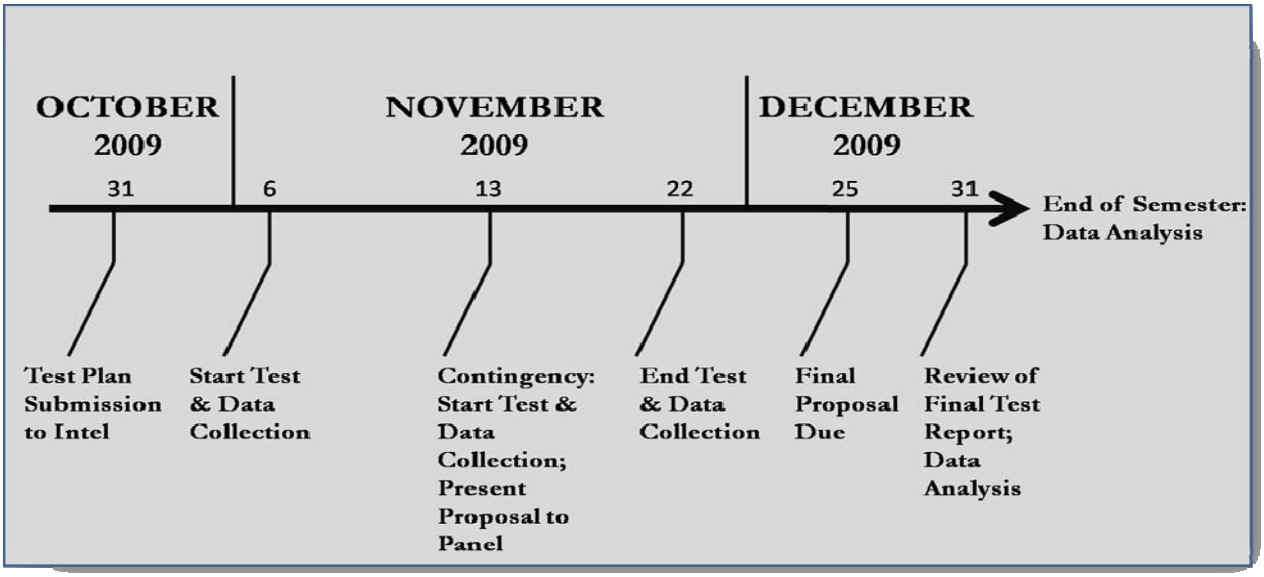
- 40 minutes indoor testing
    - 4 locations within the building (document each)
    - 5 minutes uplink, 5 minutes downlink with FIDO per each location

This testing method will be repeated per each testing site designated above. Furthermore, the testing is weekend long, and will be repeated for the following two weekends. Upon completion of testing, we will perform statistical analysis of the resulting data. This will yield answers to the following questions:

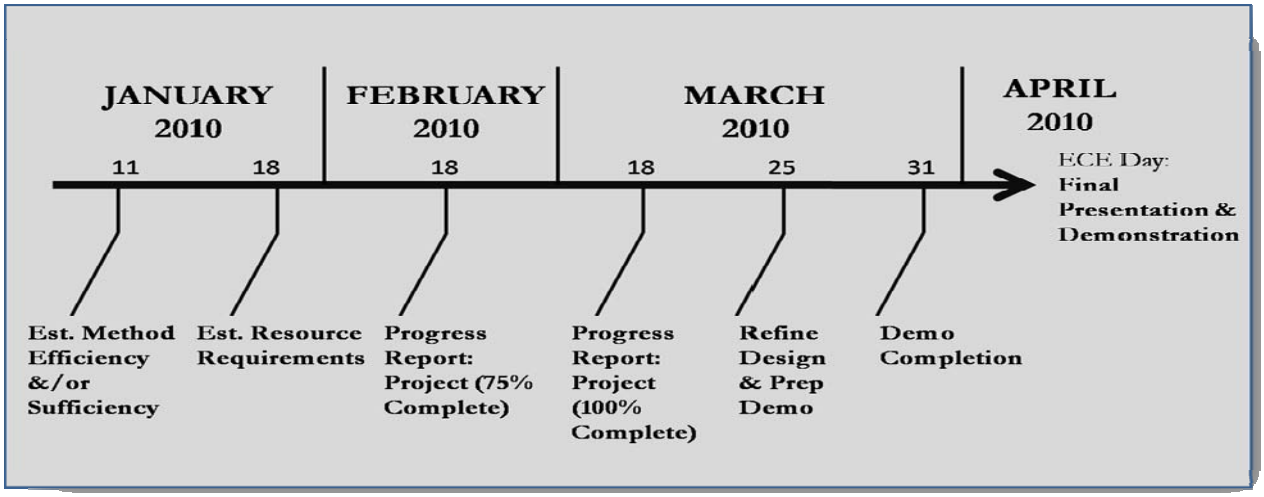
1. Is the current testing method sufficient?
2. Is the current testing method efficient?
3. Is there a means to improve this method?
4. Should a new method be implemented?

In the event that we are unable to test on the scheduled day, testing will be pushed until the all discrepancies are resolved.

Below is a timeline for Phase I:



In phase two, we will evaluate the statistical data that we derive and determine answers to the questions in the Phase I description. Below is a timeline for Phase II:



ALTERNATIVE SOLUTIONS

Intel's parameters for this design challenge constrain development of alternative solutions at time. Also, the main purpose of our project is to design an alternative to the current testing method. Upon further testing and research, we will devise and consider alternative methods.

KNOWLEDGE & COURSEWORK

The following knowledge will be used toward developing the solution:

- Practical networking knowledge
- Communications analysis
- Analytical problem solving (featured in all engineering courses)
- Working in groups efficiently (featured in most engineering courses)

The following are the courses that will be used toward the solution:

- Senior Design I & II
- Communications Theory I
- Introduction to Electrical & Computer Engineering
- Telecommunications

KNOWLEDGE TO GAIN

- Working knowledge of the WiMAX.
- Practical implementations of statistical analysis
- Practical implementations of communications systems
- Current status and the future.
- Regulations with respect to bandwidth

Tasks and Deliverables

The team has set individual and team tasks with set, major deliverables that must be produced. They are as follows:

Name	Function	Individual task(s)	Team Task(s)	Deliverables(s)
Charlery, Jonathan	Research - Technical	WiMAX Testing & Performance Research; Assist in Current Status of Art Research	Familiarity with WiMAX and all relating standards. Design a solution to the problem statement derived from Intel's need by April 2010. Full-fill design requirements.	Project Specification Document Presentation of Final Solution Working Demo for ECE Day
Gomes, Cesar	Team Lead	Maintain Design Team Focus on Agenda; Document Consolidation		
Montgomery, Brandon	Team Records; Research Current Status	Document Design Team Meetings; Current Status of Art Research; Assist in WiMAX Testing & Performance Research		
Paulos, Abeeku	Compliance & Safety Co	Design Challenge Core Team Leader (Intel Design Challenge Team Liaison); Specifications of Engineering Approach		

Project Management

TIMELINES & MILESTONES

Phase I Schedule

- October – Ramp period & Generation of student test plan
- November – Test & Measurement with Intel Checkpoint & review.
- December – Completion of Final reports & presentation to Intel & Howard Faculty.

Phase II Schedule

- January – Established WiMAX efficiency and sufficiency
- February – Seventy five percent project completion
- March – Refined Presentation Demo and Testing Analysis

- April – Final Presentation to Intel and Howard ECE Day

RESOURCES & BUDGET

Cost Analysis	Equipment	Cost
	van rentals	$4,000.00
	gasoline	$600.00
	power inverters	$300.00
	meals	$2,200.00
	Total	$7,100:

Manpower is provided by Howard University students and faculty at no monetary cost. The actual breakdown of man-hours follows:

- 10 hours per person per day actual in field. For 8 people and 9 days this is 720 man-hours. No charge.
- Weekly meetings with 10 in attendance. No charge.
- Weekly teleconference with 2 students, 2 faculty, and Intel advisor. No charge.
- Research, planning, and document preparation. 40 man-hours. No charge.

SAFETY ISSUES

The safety issues that apply to this current test plan concern logistical safety at this point. The team must account for student safety, mainly because of the technology that we will be employing. It is imperative that all students remain aware of their surroundings while testing, and do not make their selves vulnerable by separating from the team on without a team member present. In addition, we must adhere to the state of Maryland's ordinances regarding safe driving, most notably the following:

- MD Transportation Code section 21-902
- MD Transportation Code section 21-901.1
- MD Transportation Code section 21-901.1

WiMAX testing, as we stated previously, has no safety standards to adhere to.

ENGINEERING ETHICS ISSUES

The team, as engineers, must uphold to general and engineering ethics when testing. With that said, we will follow the National Society of Professional Engineers Code of Ethics

Conclusions

The proposal's intent was to communicate how Tourbillon Group will address the problem definition. The teams overall purpose is to develop a solution to evaluate the performance of a WiMAX network or device. This problem was derived from Intel's need for a means to tell how WiMAX networks or devices will perform under varying conditions. In order to arrive at a solution to the problem, we must correctly discern proper approaches towards solving this issue; research and study solutions that are currently in practice; choose a solution and alternatives; leverage the milestones and timelines provided; and create a working solution for presentation.

The approach that we will apply first is to test a working WiMAX network in Baltimore, MD over time-span of 3 consecutive weekends, collect the data, and report our findings. This is Phase I of the overall design challenge. Phase II includes leveraging the information and data collected in Phase I to create recommendations. The overall cost for the initial test results will be $7,100.00.

Our immediate objectives for the academic year are as follows:

- Completion of Testing in Baltimore, MD
- Establish Current Method's efficiency & sufficiency with Phase I Data Analysis
- Preparation for Phase II and solution design

The Tourbillon Group hopes that this proposal was to your satisfaction, and do look forward to your response in the near future.

REFERENCES

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Tektronix, *Network Diagnostics Network and Service Analyzer (NSA)*
http://www.tektronixcommunications.com/modules/communications/index.php?command=defaultPage&operation=displayDataSheet&catid=&id=442

Keithley, *Model 2820A RF Vector Signal Analyzer* http://www.keithley.com/products/rf/rfvssa/?mn=2820A

C. Mathias, *Analyze this: Low-cost wireless spectrum analyzers do the trick*
http://www.networkworld.com/reviews/2009/032309-wlan-test.html

GlobalSpec, *Spectrum Analyzers and Signal Analyzers* http://industrial-computers.globalspec.com/LearnMore/Industrial_Computers_Embedded_Computer_Components/Data_Acquisition/Spectrum_Analyzers_Signal_Analyzers

Laser 2000 of Germany *Bit Error / Timing Analysis* http://www.laser2000.de/index.php?id=362921&L=1

GlobalSpec, *Bit Error Rate Testers* http://communication-equipment.globalspec.com/LearnMore/Communications_Networking/Networking_Equipment/Bit_Error_Rate_Testers

IEEE 802.16-2005

National Society of Professional Engineers – Code of Ethics

http://www.nspe.org/Ethics/CodeofEthics/index.html

APPENDIX

DESIGN REQUIREMENT LIST

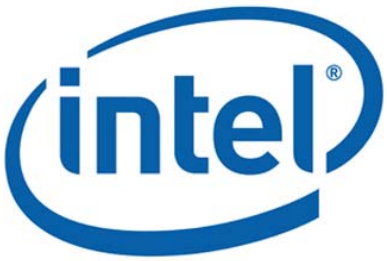
Design requriement must (1) be as quantitative, measurable, testable, and precise as possible, (2) describe the need, not the solution, (3) be comprehensive, and (4) be presented in an easy to understand format.

Design Project Title:	Intel Design Challenge - WiMAX
Team Name:	Tourbillon Group
Team Members:	Jonathan Charlery, Cesar Gomes, Brandon Montgomery, Abeeku Paulos
Date:	4-Nov-09
Version No.	3

Requirements	Desrciption(s)	Source(s)
Overall Function	To evaluate and determine the performance of WiMAX-enabled networks and/or devices by April 2010.	
Performance	1) Determine WiMAX enabled device performance under varying conditions in Baltimore, MD coverage area by December 2009 2) Evaluate the mobility aspect of the WiMAX network in Baltimore, MD (i.e. test handoff) 3) Understand indoor penetration of Wireless Broadband signals with regards to a metropolitan environment (Baltimore, MD).	Intel Corp.
Cost	Total estimate cash outlay for this project is $7100.00: $4000.00 van rentals $600.00 gasoline $300.00 power inverters $2200.00 meals N/A laptops (refer to sponsor)	Cost Analysis by Design Challenge Team; Intel Corp. covers cost
Safety	WiMAX itself adheres to IEEE, FCC, ANSI, etc standards with respect to RF radiation and the like. Testing of WiMAX networks and devices, however, have no safety standards.	
Compliance	IEEE 802.16	IEEE
Interfaces	Intel FIDO software to retrieve Key Performance Indicators (i.e. uplink bitrate/burstrate, downlink bitrate/burstrate, etc); six (6) laptops with embedded WiMAX chipset for testing and analysis; Additional interfaces to be developed.	Sponsor
Energy, Power, and Environment	Considering the travel, power inverters, and five (5) laptops in use, the current energy efficiency of the testing process as is can be considered abysmal. This will be rectified with further analysis in order to minimize the impact on energy/power consumption, as well as environmental affects.	Test Plan - Phase I
Lifespan	The standard method for testing shall evolve with the IEEE 802.16 standard.	
Size, Weight, Maintenance	Because we are in the beginning stages, there are no known parameters for size and weight. When regarding maintenance, the current method is constrained to maintanence of the current laptops to be used, as well as backing up and maintaining the data to be recovered from the testing.	
Timeline and Schedule	Extensive Test Plan for data acquisition: due 10/31/2009	Intel Corp.
	Test Plan Implementation beginning: 11/06/2009	Design Challenge Team, Intel Corp.
	End of Phase One (Test, Data Retrieval): 11/22/2009	Intel Corp.
	Beginning of Phase Two (Data Analysis, Solution Formulation): 01/11/2010	
	ECE Day Presentation: 04/2010	

Design Schedule – Phase I

Activity	Type	Owner	5-Oct	12-Oct	19-Oct	26-Oct	2-Nov	9-Nov	16-Nov	23-Nov	30-Nov	7-Dec	14-Dec	21-Dec	28-Dec	4-Jan	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	23-Oct	24-Oct
			WW41	WW42	WW43	WW44	WW45	WW46	WW47	WW48	WW49	WW50	WW51	WW52	WW53	WW54	WW55	WW56	WW57	WW58	WW59	WW43.6	WW43.7
Kickoff Call	Prework	Karen	Monday																				
Collateral Transfer	Prework	Kent	Monday																				
Kickoff F2F	Prework	Kent & Chris	Wed or Thu in DC - this is work-in-process																				
Coverage Maps	Prework	Clearwire	Friday																				
Vehicle Acquistion	Prework	Howard	Vehicle Acquisition																				
Test Plan Development	Execution	Howard Students		Test Plan Development																			
Preliminary Test Plan	Milestone Deliverable	Howard Students			Preliminary Test Plan																		
Plan Review	Review	Howard & Intel			Preliminary Test Plan																		
Updated Test Plan (with edits/changes from previous review)	Milestone Deliverable	Howard Students				Final Test Plan																	
Final Test Plan Review	Review	Howard & Intel				Friday - 0900																	
Test Data Collection	Execution	Howard Students					Test Data Collection																
Review & Feedback Sessions	Review	Howard & Intel					Friday - 0900	Friday - 0900	Friday - 0900	Friday - 0900													
Preliminary Test Report Presentation Due	Milestone Deliverable	Howard Students								Friday - 0900													
Final Analysis & Test	Execution	Howard Students									Test / Cleanup /												
Review of Final Report	Milestone Deliverable	Howard Students										Friday - 0900											



Test Plan

Student Design Challenge

Field Testing WiMAX Bit Transfer Rate in Urban Terrain

College of Engineering, Architecture, and Computer Sciences

Howard University

Washington, DC

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Executive Summary

The task at hand is two-fold. Essentially we are devising a plan to best field test a newly deployed wireless internet technology as per the customer's problem statement. We are then to implement the formulated plan. We are testing ourselves more than we are actually testing the technology.

We have assembled a heterogeneous team of different majors and classification levels into a team. We have researched a new technology few of us had little knowledge of. We learned how it operates and we determined which parameters we would monitor.

Problem Definition

Intel Corporation supports WiMAX as the up-and-coming standard in next generation wireless communications. With WiMAX proliferating across the nation and the world, it is imperative that Intel be able to best analyze a network's performance capabilities, for both optimization of the IEEE 802.16 standard, as well as consistency in their products that leverage WiMAX technology.

Considering the former, it is clear that there is a need to determine how WiMAX networks will perform under varying conditions, environments, and amongst the current wireless communication standards.

As the Howard University Design Challenge Team, we are tasked with finding the solution to this problem in an efficient, thorough, and innovative manner by leveraging our honed skills from the College of Engineering, Architecture, and Computer Sciences.

Test Plan Objectives

In order to fulfill the overall goal to analyze the performance of WiMAX networks, we devised a test plan that will provide a clearer perspective on this subject. The objectives that we designed this test plan to fulfill are as follows:

1. Establish a method for step 1 of Intel Design Challenge
2. Sufficient data recovery for analysis of a WiMAX network
3. Logistically sound travel plans in the field during test periods
4. Efficient usage of provided resources (i.e. Intel hardware & software, transportation, funding)
5. Providing a vehicle for expanded participation in the Design Challenge for students in the College of Engineering, Architecture, and Computer Sciences as a whole.
6. Expansion of team members' knowledge of WiMAX, as well as the technology that is created to support it.

Testing Methodology

The testing will be executed by teams of two, who will utilize five (5) WiMAX enabled, fully configured laptops, which will be provided by Intel. Each laptop will have the FIDO software that records the data transfer performance of the laptops. We will also be provided with 2terabyte (2TB) hard drives for backing up the data after each test period.

In formulating the test plan, we considered simple variables that can affect a wireless network's performance. First, we decided to test the fixed and mobile performance of WiMAX. Next, we considered the key performance indicators that are important to make note of:

- Upstream Bit-rate
- Downstream Bit-rate
- Received Signal Strength Indicated
- Carrier to Interference Noise Ratio
- Longitude and Latitude (in degrees.decimal)
- Ping Latency
- Connection Loss
- Location Description

We then pooled knowledge concerning the location for the testing (Baltimore, MD) and devised the logistics concerning where to test from there (to be described in a later section). Finally, we considered simple conditions in which to test the WiMAX performance under:

- Indoors
- Outdoors

Per each fixed location chosen, the testing would break down as follows:

- 3 pairs of students, each pair with a WiMAX-enabled laptop will be testing
- 1 hour allocated for testing per location
- 30 minutes Indoor testing
    - 20 minutes Downlink testing: a massively large file will be downloaded
    - 10 minutes Uplink testing: a massively large file will be downloaded

- 30 minutes Outdoor testing
    - 20 minutes Downlink testing: a massively large file will be downloaded
    - 10 minutes Uplink testing: a massively large file will be downloaded
- Data Storage to hard drives

The mobile test will consist of:

- 3 pairs of students, each pair with a WiMAX-enabled laptop will be testing
- 1 hour allocated for testing per train ride
- 2 consecutive 30 minute tests
    - 20 minutes Downlink testing: a massively large file will be downloaded
    - 10 minutes Uplink testing: a massively large file will be downloaded
- 30 minutes Outdoor testing
    - 20 minutes Downlink testing: a massively large file will be downloaded
    - 10 minutes Uplink testing: a massively large file will be downloaded
- GPS will monitor speed and location
- Data Storage to hard drives

The testing will be executed per each designated location.

For the mobile component, we decided to leverage the Baltimore Light-Rail in order to avoid the "stop and test" method implemented in previous WiMAX testing. There will be two pairs of students, each pair with a laptop. They will execute uplink and downlink testing while riding on the Light-Rail from Baltimore-Washington International Airport and up to the Towson area of Baltimore, MD.

The server the laptops will be uploading to and downloading from is a server located in the Systems and Computer Sciences Department of the College of Engineering and Architecture and Computer Sciences at Howard University. The server will be accessed by IP address, being that it does not have a Fully Qualified Domain Name in the relevant Domain Name Service servers.

The server specifics are enumerated below:

- Dell PowerEdge 2600, 3.20 GHz, 4GB RAM
- Operating System: Windows Server 2003
- Maximum Connections: 100,000
- IP address: 138.238.130.238

The specifics of the file to be transferred during the test are listed below:

- large ISO9660 file
- file sizes: 1.5 GB

.

Key Success Indicators

The data will be analyzed from the 5 laptops from the 9 days of field testing. The data will be analyzed for each of the 3 stationary sites and the light rail run, and will be compared with data for the other weeks at that site. If the data collected from a particular day of week and site have a does not exhibit an inexplicable variance from the mean, the test will be considered a success.

It is our intent not to compare apples with oranges. This is to say that a test at the Towson's Starbucks on Friday from 10:00 to 11:15 a.m. will only be compared with the other two Fridays at Starbucks from 10:00 to 11:15 a.m. Once a "tightness" of data is observed for each scenario, the data sets will combine to provide general statistical information for each site. That is to say after establishing acceptable variance for the individual tests, the performance at each site (irrespective of indoor/outdoor, time of day, day of week) will be compared with the other sites.

Where significant variances from the mean are observed on, the team will seek to explain the difference.

Where the mean bit-rates for a particular site are consistently and significantly different from the bitrates of other runs, we will suggest possible reasons for the anomaly the examination of network topology, field terrain features, or other perceived factor.

Team Qualifications

The students that are participating in this challenge are of varying classifications, disciplines, and experiences. The Design Challenge Team, as defined by the challenge requirements, is comprised of a core team of eight (8) students, but is capable of including the student body as an extension of the core team. The core team leading this effort has a minimum of 3 full years of study at Howard University in Electrical Engineering, Computer Engineering, and Computer Sciences. These disciplines are core to Intel's business. The coursework that each core team member has experienced provides the basics in project management, group work, analysis, and project completion and delivery. In addition, the student body, of whom the extended team may be pooled from, are all experiencing and learning from similar coursework. Therefore, the collective knowledge and points of view within the Design Challenge Team will provide a solution to the problem at hand, and, more immediately, professionally execute the devised test plan.

Team Members

The core student team consists of 8 members. The team is a mix of electrical engineering students and computer engineering students. There are both graduate and undergraduate students.

Core Team:

- Abeeku M. Paulos (team leader) - Electrical Engineering - Undergraduate (Senior)
- Cesar Gomes (team co-leader) – Computer Engineering – Undergraduate (Senior)
- Brandon Montgomery – Electrical Engineering – Undergraduate (Senior)
- Jonathan Charlery – Computer Engineering – Undergraduate (Senior)
- Nana Osafo – Computer Sciences – Graduate (2nd Year)
- Tracy Adams – Computer Engineering – Undergraduate (Senior)
- Makan Keita – Computer Sciences – Graduate (1st Year)
- Alisha Kellerman – Computer Sciences – Graduate (1st Year)

All of the above members can be reached though:

- group email account "HU_Intel_Challenge_Group@yahoogroups.com"
    - student leads:
        - A.M. Paulos: apaulos@howard.edu
        - Cesar Gomes: gomes.cesar.a@gmail.com
    - faculty advisors:
        - John Trimble, PhD: jtrimble@howard.edu
        - Charles Kim, PhD: ckim@howard.edu

Vehicle Operators

This project will require the use of rental vehicles. The vehicles will be rented from Enterprise 2730 Georgia Avenue NW 20001-3817, phone number (202)332-1716. The names of the drivers follow. The driver's license data has been excluded from this form for reasons of personal privacy. The can be found in an attached addendum. All drivers have valid US drivers licenses and are of 25 years of age or older.

- Makan Keita
- Nana Yaw Afum Osafo
- Abeeku M. Paulos
- Tracy Adams

Testing Schedule

Synopsis:

Tests will be conducted over Friday, Saturday, and Sunday, for 3 consecutive weeks in November. 2 four-person teams will depart from Howard University 8:00 a.m. on Fridays, and return at 7:00 p.m. that evening. Saturdays and Sundays the team will depart at 10:00 a.m. and return at 9:00 p.m.

There will be an hour long on-site test using Wi-Fi (IEEE 802.11g) from a laboratory in Howard University, several days before field testing. The purpose of this preliminary test will be:

- To familiarize the team with the equipment, user interface, data collected, and operation in general.
- To test the laptops, in particular to monitor battery life. It is desirable to have the laptops on battery power and have the WiMAX radio on during the test duration. The lab is not in the WiMAX service area, but the radio should default to seek mode, increasing the battery load.
- To stress test the servers we will be utilizing, to ensure that the server and its router can support the massive simultaneous file uploads and downloads the tests demand.

Itinerary:

The detailed itinerary is listed on the following pages in table form.

FRIDAYS			
	Team A	Team B	Rail Detachment
0800-0845	Leave Home Station (Howard Univ), depart for BWI Airport light-rail station (all hands)	Leave Home Station (Howard Univ), depart for BWI Airport light-rail station (all hands)	
0845-0900	Arrive at BWI. Deploy 4-person, **2**-laptop detail to rail detachment. (2-person, 1-laptops remain with vehicle)	Arrive at BWI. Deploy 2-person, 1-laptop detail to rail detachment. (4-person, 1-laptop remain with vehicle)	Compose 6-person, 3-laptop team by drawing 4 people & 2 laptops from team A and 2 people 1 laptop from team B.
0900-0915			Board 0910 northbound train with rail passes.
0915-0945	Depart BWI for Towson Starbucks	Depart BWI for Towson Starbucks	Commence Test Set #1 (40 min large file download, followed by 20 min large file upload)
0945-1000	Arrive at Towson Starbucks and position units. Team Driver departs for light rail station to retrieve Rail Detachment.	Arrive at Towson Starbucks and position units.	(continue Test Set #1)
1000-1015	Commence Test Set #2-int	Commence Test Set #2-ext	Conclude Test Set #1, disembarck rail at Lutherville Station @ 1011h, await extraction from Team #1 driver.
1015-1030	Conclude Test Set #2-int	Conclude Test Set #2-ext	Transported back to respective teams for reintegration.
1030-1045	Position Operators for Test Set #2-ext	Position Operators for Test Set #2-int	Personal Hygiene
1045-1100	Commence Test Set #2-ext	Commence Test Set #2-int	Debrief and reintegration into their respective teams.
1100-1115	Conclude Test Set #2-ext. Receive Rail Detachment component for reintegration. Depart Towson Starbucks	Conclude Test Set #2-int. Receive Rail Detachment component for reintegration. Depart Towson Starbucks	
1115-1130	Drive time	Drive time	
1130-1230	Lunch and After-Action Review of morning activities.	Lunch and After-Action Review of morning activities.	
1230-1245	Arrive at Morgan State University, position operators for Test Set #3.	Arrive at Morgan State University, position operators for Test Set #3.	
1245-1315	Test Set #3-int	Test Set #3-ext	
1315-1330	Transition into 2nd phase of Test Set #3	Transition into 2nd phase of Test Set #3	
1330-1400	Test Set #3-ext	Test Set #3-int	
1400-1415	Secure from Test Set #3, mount up vehicles.	Secure from Test Set #3, mount up vehicles.	
1415-1430	Drive time	Drive time	
1430-1445	Arrive at Johns Hopkins University, position operators for Test Set #4.	Arrive at Johns Hopkins University, position operators for Test Set #4.	
1445-1515	Test Set #4-int	Test Set #4-ext	
1515-1530	Transition into 2nd phase of Test Set #4	Transition into 2nd phase of Test Set #4	
1530-1600	Test Set #4-ext	Test Set #4-int	
1600-1630	Secure from data collection operations. Replicated all data to USB external TB drives	Secure from data collection operations. Replicated all data to USB external TB drives	
1630-1645	Drive time	Drive time	
1645-1745	Dinner and After-Action Review of afternoon activities.	Dinner and After-Action Review of afternoon activities.	
1745-1900	Return to Home Station. Secure vehicles and equipment.	Return to Home Station. Secure vehicles and equipment.	

SATURDAYS AND SUNDAYS			
	Team A	Team B	Rail Detachment
1000-1045	Leave Home Station (Howard Univ), depart for BWI Airport light-rail station (all hands)	Leave Home Station (Howard Univ), depart for BWI Airport light-rail station (all hands)	
1045-1000	Arrive at BWI. Deploy 4-person, **2**-laptop detail to rail detachment. (2-person, 1-laptops remain with vehicle)	Arrive at BWI. Deploy 2-person, 1-laptop detail to rail detachment. (4-person, 1-laptop remain with vehicle)	Compose 6-person, 3-laptop team by drawing 4 people & 2 laptops from team A and 2 people 1 laptop from team B.
1100-1115			Board 1110 northbound train with rail passes.
1115-1145	Depart BWI for Towson Starbucks	Depart BWI for Towson Starbucks	Commence Test Set #1 (40 min large file download, followed by 20 min large file upload)
1145-1200	Arrive at Towson Starbucks and position units. Team Driver departs for light rail station to retrieve Rail Detachment.	Arrive at Towson Starbucks and position units.	(continue Test Set #1)
1200-1215	Commence Test Set #2-int	Commence Test Set #2-ext	Conclude Test Set #1, disembarck rail at Lutherville Station @ 1211h, await extraction from Team #1 driver.
1215-1230	Conclude Test Set #2-int	Conclude Test Set #2-ext	Transported back to respective teams for reintegration.
1230-1245	Position Operators for Test Set #2-ext	Position Operators for Test Set #2-int	Personal Hygiene
1245-1300	Commence Test Set #2-ext	Commence Test Set #2-int	Debrief and reintegration into their respective teams.
1300-1315	Conclude Test Set #2-ext. Receive Rail Detachment component for reintegration. Depart Towson Starbucks	Conclude Test Set #2-int. Receive Rail Detachment component for reintegration. Depart Towson Starbucks	
1315-1330	Drive time	Drive time	
1330-1430	Lunch and After-Action Review of morning activities.	Lunch and After-Action Review of morning activities.	
1430-1445	Arrive at Morgan State University, position operators for Test Set #3.	Arrive at Morgan State University, position operators for Test Set #3.	
1445-1515	Test Set #3-int	Test Set #3-ext	
1515-1530	Transition into 2nd phase of Test Set #3	Transition into 2nd phase of Test Set #3	
1530-1600	Test Set #3-ext	Test Set #3-int	
1600-1615	Secure from Test Set #3, mount up vehicles.	Secure from Test Set #3, mount up vehicles.	
1615-1630	Drive time	Drive time	
1630-1645	Arrive at Johns Hopkins University, position operators for Test Set #4.	Arrive at Johns Hopkins University, position operators for Test Set #4.	
1445-1515	Test Set #4-int	Test Set #4-ext	
1715-1730	Transition into 2nd phase of Test Set #4	Transition into 2nd phase of Test Set #4	
1730-1800	Test Set #4-ext	Test Set #4-int	
1800-1830	Secure from data collection operations. Replicated all data to USB external TB drives	Secure from data collection operations. Replicated all data to USB external TB drives	
1830-1845	Drive time	Drive time	
1845-1945	Dinner and After-Action Review of afternoon activities.	Dinner and After-Action Review of afternoon activities.	
1945-2100	Return to Home Station. Secure vehicles and equipment.	Return to Home Station. Secure vehicles and equipment.	

Cost Analysis

- This project will require the use of 2 rental vans.
    - The rental office (Enterprise, 2730 Georgia Ave NW 20001, (202)332-1716) does not open Weekdays until 7:30 a.m., and does not give us ample time before our scheduled 8:00 a.m. departure time. Therefore the vehicles must be picked up the day before (on Thursday). This would afford us the time needed to acquire and out fir the vehicles with the power inverters.
    - The vehicle rental is closed on Sundays, therefore the vehicle need to be returned the following Monday.
    - A Thursday noon through Monday noon rental of a Dodge Caravan or Chrysler Town & Country minivan is $576.39 plus $52.40. This does not include insurance. That is the same rate as the full weekly rate. The total estimate is $3772.74 ($628.79 per vehicle X 2 vehicles X 3 weeks).
    - We will be using approximately 10 gallons of gasoline for each vehicle per day (10 gallons X 9 days X 2 vehicles = 180 gallons). At $3.00 per gallon, gas expenditures should be near $540.
    - The vehicles could be picked up on Fridays, but that allows for little margin of error. It can be done if needed. However, the rental office is closed on Sundays, so vehicle return that day is not possible. Telephonically, a customer service representative (Sanjeed) said that he could have the vehicles available for pick-up Thursday evening and they could be returned first thing Monday morning, but he would needs final approval from the site manager. He states that shouldn't be a problem.
- We will be requiring the use of a power inverter for each van, to power the laptops over the 8 hour mission.
    - Wal-Mart has Cobra 1500W inverters for $137 plus tax. We would need 2 (1 per van). This item has been ordered on line. We could also acquire a comparably priced item locally.
- Meal in the field will be $10 lunch and $20 dinner per each of the 8 persons for each of the 9 days. This expenditure is estimated to be $2160.
- WiMAX laptops, GPS units, and dongles are being provided by Intel. The actual cost of this line item to them is unknown to us.

- Manpower is provided by Howard University students and faculty at no monetary cost. The actual breakdown of man-hours follows:
    - 10 hours per person per day actual in field. For 8 people and 9 days this is 720 man-hours. No charge.
- Weekly meetings with 10 in attendance. No charge.
- Weekly teleconference with 2 students, 2 faculty, and Intel advisor. No charge.
- Research, planning, and document preparation. 40 man-hours. No charge.
- The total estimated cash outlay for this project is $7,100:
    - $4000.00 van rentals
    - $600.00 gasoline
    - $300.00 power inverters
    - $2200.00 meals

Contingency Plan

In the event all the resources are not available at the planned start, the project will be start one week later than planned. In that case, field surveys would collect on Mondays as well and would be performed by graduate students.

If on the first day of field testing, it is determined that the first stationary tests (at Towson) can be performed by all 5 laptops after the conclusion of the mobile tests without causing significant delay to the rest of the itinerary, all laptops will be used on subsequent days mobile tests.

Conclusion

We have formulated a plan that is manageable and should produce quantifiable results. Through the effective deployment of resources we should be able to effectively perform field tests and analyze the collected data to satisfy the problem statement.

It is unknown at this time what results should be expected. However, by the completion of this project, any team member should feel confident in devising and administering a test plan, even on subject matters he or she is not an expert on.

Addenda

Google Drive times

Light Rail System Map

Light Rail Route Schedule – Northbound: Weekdays

Light Rail Route Schedule – Northbound: Saturdays

Light Rail Route Schedule – Northbound: Sundays

Driver Personal Data

Drive Times

Driving directions to 2400 6th St NW, Washington, DC 20059
112 mi – about **2 hours 30 mins** (up to 3 hours 30 mins in traffic)

A 2400 6th St NW
Washington, DC 20059

1.	Head **south** on **6th St NW** toward **Howard Pl NW**	0.2 mi
2.	Turn **left** at **Bryant St NW**	0.6 mi
3.	Turn **right** at **N Capitol St NW**	0.8 mi
4.	Slight **right** toward **New York Ave NW/US-50 E**	0.1 mi
5.	Take the 1st **left** onto **New York Ave NW/US-50 E** Entering Maryland	4.0 mi
6.	Take the **Balt-Wash Pkwy** exit on the **left** toward **Baltimore**	0.5 mi
7.	Merge onto **MD-295 N**	23.3 mi
8.	Take the exit onto **I-195 E** toward **B w I Airport**	1.6 mi
9.	Take the exit	0.1 mi
10.	Slight **right**	361 ft

31.4 mi – about 33 mins
up to 55 mins in traffic

B Baltimore-Washington International-Bwi
BWI: Baltimore Washington International Airport
Baltimore, MD 21240
(410) 859-7111

11.	Head **northwest**	361 ft
12.	Turn **right** onto the ramp to **I-195 E/Metropolitan Blvd**	161 ft
13.	Turn **right** at **I-195 E/Metropolitan Blvd**	0.1 mi
14.	Continue onto **Elm Dr**	0.1 mi
15.	Slight **right** at **Elm Rd**	1.0 mi
16.	Continue onto **Elm Dr**	0.1 mi
17.	Continue onto **I-195 W**	3.9 mi
18.	Take the exit onto **I-95 N**	2.2 mi
19.	Take exit **49B** on the **left** for **I-695 W** toward **Towson**	0.7 mi
20.	Merge onto **I-695 N**	16.4 mi
21.	Slight **right** at **I-83 N** (signs for **I-83 N/Timonium/York Pa**)	1.4 mi
22.	Take exit **16A** toward **Timonium Rd/Timonium E**	0.2 mi
23.	Turn **right** at **W Timonium Rd**	0.3 mi
24.	Turn **right** at **W Aylesbury Rd**	0.5 mi
25.	Take the 2nd **right** toward **W Ridgely Rd**	0.3 mi

26. Turn **right** at **W Ridgely Rd** 489 ft
Destination will be on the right

27.4 mi – about 30 mins
up to 45 mins in traffic

C 150 W Ridgely Rd
Lutherville-Timonium, MD 21093

27. Head **east** on **W Ridgely Rd** toward **Francke Ave** 0.3 mi

28. Turn **right** at **MD-45 S/York Rd** 2.2 mi

29. At the traffic circle, take the **2nd** exit onto **Dulaney Valley Rd/York Rd**
Continue to follow York Rd 0.5 mi
Destination will be on the right

2.9 mi – about 7 mins

D 31 York Rd
Towson, MD 21204

30. Head **south** on **MD-45 S/York Rd** toward **W Burke Ave** 3.4 mi

31. Turn **left** at **E Cold Spring Ln** 1.5 mi

32. Turn **left** 92 ft

4.9 mi – about 14 mins

E Morgan State University
Baltimore, MD

33. Head **south** toward **E Cold Spring Ln** 92 ft

34. Turn **right** at **E Cold Spring Ln** 2.1 mi

35. Turn **left** at **N Charles St** 0.3 mi

36. Turn **left** to stay on **N Charles St** 1.1 mi
Destination will be on the left

3.6 mi – about 12 mins

F 3400 N Charles St, Baltimore, Maryland

37. Head **south** on **N Charles St** toward **Art Museum Dr** 0.2 mi

38. Slight **right** at **W 29th St** 0.5 mi

39. Take the ramp to **I-83 S/Jones Falls Expy** 0.2 mi

40. Keep **left** at the fork, follow signs for **I-83 S/Jones Falls Expy** and merge onto **I-83 S/Jones Falls Expy** 2.5 mi
Continue to follow I-83 S

41. Turn **right** at **E Fayette St** 0.9 mi

42. Turn **left** at **Baltimore Washington Pkwy/N Greene St/MD-295 S** 31.5 mi
Continue to follow Baltimore Washington Pkwy/MD-295 S

43. Take the exit onto **New York Ave NE/US-50 W** toward **Washington** 4.3 mi
Entering District of Columbia

44. Turn **right** at **Florida Ave NE** 1.1 mi

45. Turn **right** at **Georgia Ave NW** 0.4 mi

46. Turn **right** at **Howard Pl NW** 335 ft

47. Turn **left** at **6th St NW** 197 ft
Destination will be on the left

41.8 mi – about 51 mins
up to 1 hour 20 mins in traffic

2400 6th St NW
Washington, DC 20059