# MAXWell Lab: Building a WiMAX Forum Applications Laboratory

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***Abstract*— This paper describes the design and deployment of the University of Maryland MAXWell Laboratory, a WiMAX Forum Applications Laboratory. In an effort to increase research and development of WiMAX-specific applications, the WiMAX Forum established a program for endorsing testbeds located at vendor-neutral locations as venues for research and collaboration into new "killer apps" for WiMAX.**

**The MAXWell Lab is one such venue, and this paper describes the basic design, architecture, and deployment of this campus-wide testbed. Additionally, we describe possible directions in applications research, and the MyeVyu system currently under development at the University of Maryland.**

## I. Introduction

Mobile WiMAX offers a tremendous opportunity for true mobile broadband, however as with any network technology its market adoption is motivated by applications. If users have no need for 10Mbps to their handset, why strive to deliver it?

Much of WiMAX's development so far has focused on a bottom-up, PHY/MAC technology push. The goal was to develop a strong wireless communications technology that could support a whole new class of applications. However until those applications are developed and marketed to consumers, consumers have no strong motivation to be interested in WiMAX.

To initiate an application-driven development of WiMAX, the WiMAX Forum's Applications Working Group created a program for the development of WiMAX Forum Applications Labs where researchers and vendors could work together to create and test next-generation "killer apps" that utilize WiMAX as their underlying communications technology.

In this paper we discuss the MAXWell Lab created at the University of Maryland, and describe classes of applications applications possible when using WiMAX and the IP Multimedia Subsystem (IMS).

The remainder of this paper is organized as follows. Section two motivates the WiMAX Forum's applications labs. Section three describes the MAXWell lab's architecture and capabilities. Section four outlines numerous classes of applications applicable to WiMAX. Section five details the MyeVyu application developed at the University of Maryland as a case study in a mobile broadband-enabled application. Section six concludes.

## II. WiMAX Applications Laboratories

The WiMAX Forum Applications Lab program was created for a number of reasons. The first is to promote WiMAX using a top-down approach. By facilitating research and development of WiMAX applications, the WiMAX industry will be able to show consumers new functionality that was previously unavailable to them. So far WiMAX has simply been marketed as a "fatter pipe" to mobile users which is often difficult to fully utilize using the small screen of a handset.

In addition to general technology promotion, the labs' specific function is to provide a venue for software vendors to test their applications in a vendor-neutral environment using a scaled-down, highly-instrumented deployment of carrier-grade equipment.

Specific requirements for a WiMAX Forum Applications Lab are as follows:

- work with application vendors to support testing their applications;
- utilize equipment from at least two vendors;
- be committed to holding annual open-house events; and
- be operated by non-commercial institutions.

The WiMAX Forum Applications Lab Task Group has so far endorsed two labs, the M-Taiwan WiMAX Applications Lab, and the UMD MAXWell Lab.

The lab was the first lab established in conjunction with the WiMAX Forum, under the Applications and Business Task Group. ITRI built the laboratory and the WiMAX Forum endorsed it. The initial phase involved deploying two WiMAX basestations with coverage of the entire ITRI Chutung Campus, with an Internet connection. The network used 2.5GHz frequency spectrum, and

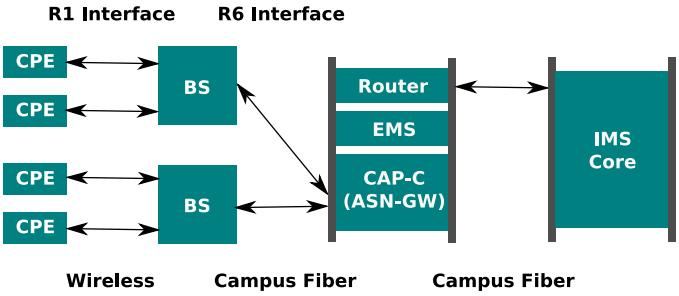


Fig. 1. Diagram of the basic WiMAX network layout, including air interface, BS-ASN interface, and IMS core connection

could be accessed using a PCMCIA card in a standard laptop computer. Its initial demonstration included eight applications including two major IPTV-based streaming multimedia services. Since then they have added four more basestations and a number of new applications are in the works. The lab provides testing capabilities to application providers for testing mobile broadband applications over WiMAX in an environment allowing testing of tower handover and mobility. Their operations center provides a location for testing and demonstrating applications.

The emphasis of this paper is on providing a detailed description of the MAXWell WiMAX Applications Laboratory located at the University of Maryland. The next section will detail its architecture and deployment, to demonstrate its testing capabilities.

## III. MAXWell Lab Architecture

The MAXWell Laboratory, once initial phases of installation and systems integration are complete, will contain two Motorola WAP400 basestations, the Motorola Access Service Network Gateway (ASN-GW) called the CAP-C, and connectivity to an Ericsson IP Multimedia Subsystem (IMS) core. The following sections detail the basic network layout of the system, the PHY/MAC-level parameters and configuration, and the instrumentation allowing for simulation analysis and control.

### A. Testbed Network Architecture

The MAXWell Laboratory is being deployed in phases. The initial phase involves deployment of two Basestation Control Units (BCUs) each with three sectorized RF heads to two campus rooftops (see Figure 2. One is located on top of the A.V. Williams building, home to the CS and ECE departments. The other is located on top of a residence hall for undergraduates, and at twelve stories it is one of the tallest building on campus. The ASN-GW (aka Motorola CAP-C), Element Management System (EMS), and primary network router are all located in the MAXWell Lab Network Operations Center (NOC) in the A.V. Williams building.

The connections between each basestation (BS) and the ASN-GW are the WiMAX R6 interface. These links contain both control frames between the ASN-GW and BSes, along with user traffic to and from each CPE. While some systems separate this traffic using GRE tunnels over IP networks, the MAXWell lab uses VLAN separation. Connections are patched across the University of Maryland campus fiber ring using gigabit Ethernet (GigE) with IEEE 802.1q VLAN tagging over dedicated single-mode fiber.

The IMS core is located at the Laboratory for Telecommunications Sciences, and is also patched into the network using a GigE connection over dedicated, single-mode fiber. The IMS core adds a service plane to the network architecture, and allows accounting and billing on a per-service or per-application basis, rather than simple per-bit charging. The initial version uses an FOKUS open-source IMS core from [2].

In Phase II, the MAXWell Lab intends to add additional basestations from a vendor other than Motorola, as recommended by the WiMAX Forum, and will add an Ericsson IMS core as an additional service plane for development and testing. With Phase II, the MAXWell lab will be a fully-featured environment for testing commercial applications with diverse equipment in a realistic network environment.

### B. Air Interface Configuration

The network will be operating in the 2.5 GHz to 2.7 GHz frequency band. Currently the testbed has frequency licenses for two 6 MHz channels (given the current sub-channeling of that band by the FCC) in which it plans to operate two 5 MHz carriers. Consequently the devices are using the 512-point FFT with 10.94 kHz sub-carrier separation, 102.86 $\mu$s symbol duration, and a total of 48 OFDM symbols per 5ms frame.

The Motorola WAP 400 supports diversity space-time block coding, i.e. Alamouti's Code [3], also known as WiMAX Matrix A, a form of Multiple Input Multiple Output (MIMO) technology. In this mode two basestation antennas are used to transmit two unique data symbols during time slot 1, and their conjugates in time slot 2. Clients can then add and subtract the data received at their antenna over the two time slots to resolve the original two symbols, while achieving a diversity gain in effective signal to noise ratio. The MAXWell lab network

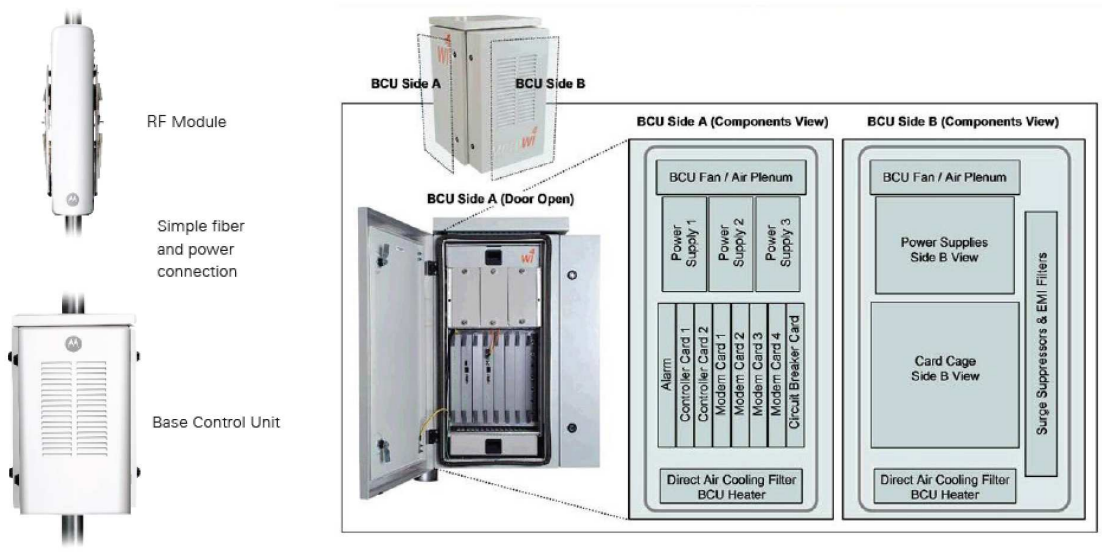


Fig. 2. Basestation Control Unit (BCU) and RF head: (left) picture of the RF head which is mounted near the antenna, and the BCU which controls up to four RF heads; (right) diagram of the BCU internal components [1]

can be configured to both use MIMO and not use MIMO, depending on the requirements of the application being tested.

Figure 3 shows the location of the initial two basestation deployments. The basestations are 600 meters apart and provide full outdoor coverage of the engineering portion of campus. Future deployments will include basestations scattered throughout the rest of campus to provide full-campus coverage.

Initial experimentation has shown the ability to close a video-conferencing link to a mobile vehicle at distances of up to 1000 meters. As of April 2009, with the deployment of the first permanent base station sector, coverage of roughly 0.25 km$^2$ of campus was achieved, with a sector radius of nearly 700 meters.

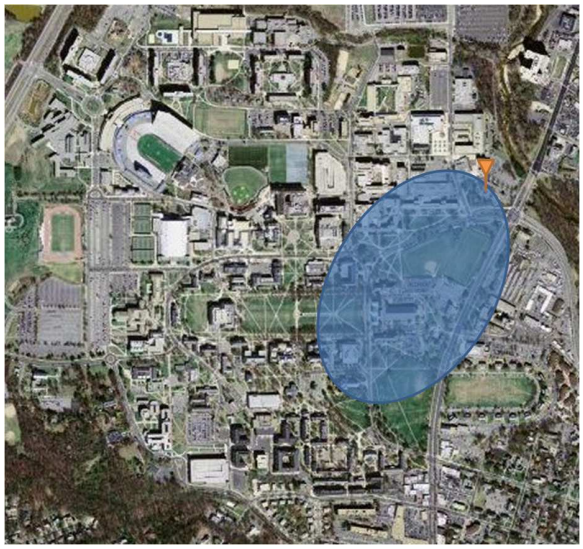

Fig. 4. Measured rough coverage area from initially-deployed base station sector for the first base station installation, covering approximately 0.25 km$^2$.

### C. Testbed Instrumentation

Phase I of the testbed roll-out allows users of the network to collect and monitor traffic traveling over each individual core link of the system. In particular, packet data traversing each of the connections between the CAP-C and basestations is logged to a centralized database for analysis. These PCAP-format packet traces include timestamps and are annotated as to the link from which they were collected.

Phase II of the testbed roll-out will include RF-level instrumentation of the network. RF sensors will be installed at key locations throughout the University of Maryland campus. These sensors will be capable of down-converting the received RF spectra to baseband, digitizing segments of it, buffering it, and then transporting it across the campus network infrastructure to a centralized repository. Currently the plan is to utilize the Universal Software Radio Peripheral Version 2 (USRPv2) [4] with the RFX2400 daughter-board [5]. This connected to a PC would allow significant RF instrumentation, to include transmission of various in-

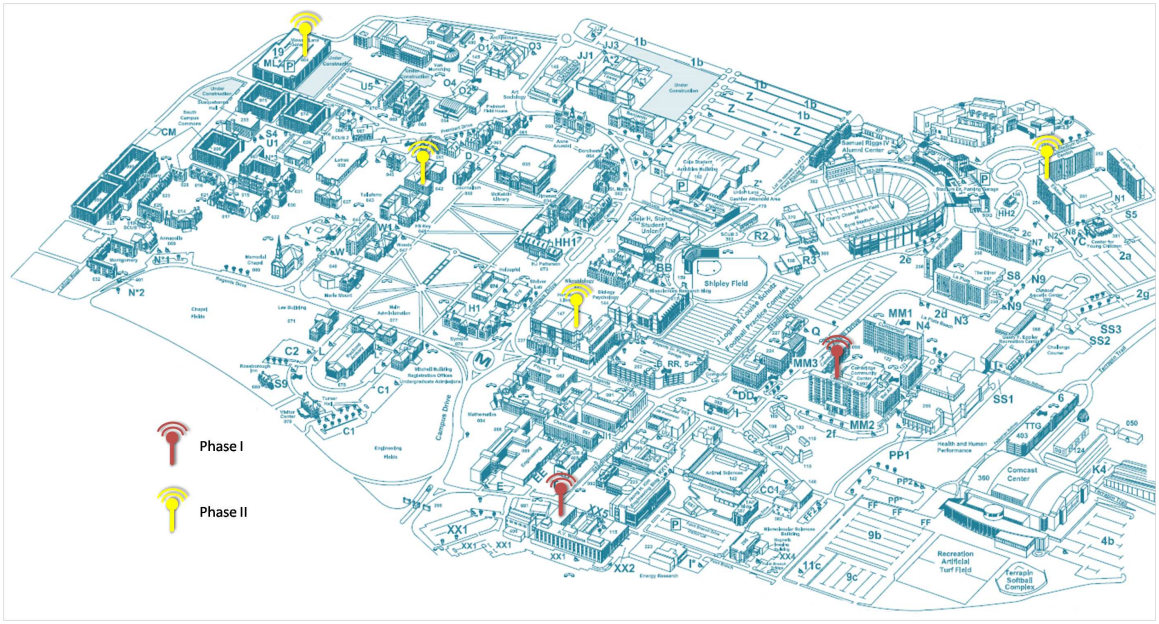


Fig. 3. University of Maryland campus map, indicating locations Phase I basestation deployment, and likely Phase II basestations

terference signals, or implementation of an SDR-based WiMAX client.

From the NOC, operators and experimenters can control every aspect of the testbed configuration, including manipulation of the basestation configurations, logical network topology, and data services operating on the network.

## IV. Applications

The goal of this testbed is to provide a realistic environment in which to test WiMAX applications. In this section we describe some applications, and how WiMAX is uniquely poised to support them.

### A. Location-Based Services

Location-Based Services (LBS) are applications which utilize a mobile subscriber's currently geographic location as a part of the underlying service. Turn-by-turn navigation applications that utilize a mobile handset's GPS are an example of LBS.

Within WiMAX, there are numerous ways to obtain a handset's location. First, knowing which sector of which basestation to which a client is connected can provide a coarse-grained location. For a cell with three sectors and coverage radius of 500 meters, this is roughly 25,000 $m^2$, or 0.025 $km^2$. By taking advantage of the tower ranging messages used in the underlying MAC protocol, the basestation can determine a distance, generally to within 100s of meters. This can decrease the area of possible location to roughly 10,000 $m^2$.

Both clients and basestations can use numerous timing and power-based techniques to obtain even better location estimates, using algorithms such as Time Difference of Arrival (TDOA). These approaches typically require chipset implementations that can report precise timing and power information from received sub-frames. Section V discusses this further in the context of the MyeVyu application.

Certainly the most accurate approach is to use a GPS embedded within the client device. The client can report its latitude and longitude to individual applications utilizing LBS.

With LBS, many applications become possible, including friend-finding and plugins for Web 2.0 services like Twitter and Facebook; location-specific directory service, news, advertisements, weather, and traffic; and turn-by-turn navigation.

### B. Multimedia Services

Given the ability to deliver rates of up to 10 Mbps to handsets, depending on the cell loading, a wealth of multimedia services are possible through WiMAX. Streaming television and radio are the major contributors to this area, but WiMAX could enable two-way pics/video messaging, video conferencing, and VoIP as well.

### C. IMS-Based Services

Given the immense bandwidth available to mobile subscribers, the ability to capitalize on it is important. Simply charging per bit transfered can limit operator revenue since the value per bit differs from application to application. The IP Multimedia Subsystem (IMS) provides a mechanism for providing service-level access control and billing for mobile subscribers.

IMS can be used to meter multimedia services, including VoIP and IPTV. It can also be used as a framework to support presence-based applications such as chat and LBS. The Session Initiation Protocol (SIP) is the foundation of IMS, and is used throughout to provide signalling and control of IMS sessions. Authentication, Authorization, and Accounting (AAA) services are used to authenticate users and account for their activities [6].

By providing an IMS core within the MAXWell laboratory, application developers will have a true environment for testing multimedia and presence services using commercial-grade services likely to be found in the networks of operators to which they may wish to sell their applications.

## V. UMD's MyeVyu Application

MyeVyu is a new application that is being developed by the MAXWell and MIND Labs at the University of Maryland. The goal is to build a system that will not only make the University of Maryland campus safer, but that it will improve the overall quality of life on campus. One part of the system is providing users with location-aware, context-sensitive information and support. This means that the user can contact a Police dispatcher by simply pressing a button on their mobile device. Unlike calling the police, the button will provide the dispatcher with a great deal more information including the user's ID and location, in addition to an audio and video stream that will allow the dispatcher to hear, view, and record the information from the incident scene. The idea is that this will help catch criminals more quickly, rescue victims at a faster rate, and possibly discourage crimes from being committed in the first place.

The MyeVyu system also provides the user with access to a multitude of relevant information. The information provided includes current weather, campus events, the location of vending machines, directions to any location on campus, meeting times and locations, and support for handicapped concerning accessible paths. The system will even provide additional information about suitable shuttles to use and their current locations, as well as the location of your vehicle in a lot on campus.

Currently MyeVyu supports device localization using both power [7] and time [8] measurements of the university WLAN infrastructure. The software operates on both the Apple iPhone and the Nokia i810 tablet PC. Though all the existing connectivity is via WiFi, efforts are currently underway to support MyeVyu over the WiMAX infrastructure supported by the MAXWell laboratory. Once this is complete, MyeVyu will be a perfect example of a WiMAX-enabled application that can significantly change the way people interact with their environment through technology.

## VI. Conclusion

In this paper we described the WiMAX Forum's initiative to promote applications research through the use of WiMAX Forum Applications Laboratories. Additionally, we described the architecture and deployment of the MAXWell Lab, an applications lab at the University of Maryland. A brief look into applications and MyeVyu were presented.

Over the next year, the MAXWell laboratory will be expanding operations, offering testbed services to application developers and vendors, and be conducting internal research specifically in the area of presence-based applications. In the near future, we will see an entirely new class of technology emerge that utilizes advanced access network capabilities, service-level user management, and Web 2.0 advancements.

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