



WiMAX  
FORUM

**PLUGFEST**

24 September - 1 October 2006  
Bechtel Labs, USA

## White Paper

Mobile WiMAX Plugfest

September 24-30, Frederick, MD, USA

Hosted by: Bechtel Telecommunications

In collaboration with The WiMAX Forum and CETECOM Labs

### Table of Contents

Introduction..... 3

WiMAX Forum overview ..... 4

WiMAX Technology framework ..... 4

Key elements of WiMAX Technology..... 4

WiMAX Plugfest Testing ..... 6

Test architecture ..... 6

SUT #1: Configuration with Single BS and Single MS (One Vendor)..... 6

SUT #2: Configuration with Single BS and Single MS (Two Vendors) ..... 6

SUT #3: Configuration with Single BS and Two MS (from Same Vendor)..... 7

SUT #4: Configuration with Single BS and Two MS (from Different Vendors) ..... 7

SUT #5: Single BS and Three MS (Three Different Vendors) ..... 7

Test Plan8

Key Learnings, Observations, and Future Work ..... 12

Terminology..... 13

Acknowledgments ..... 14

Copyright 2006. "WiMAX," "WiMAX Forum," the WiMAX Forum logo, "WiMAX Forum Certified," and the WiMAX Forum Certified logo are trademarks of the WiMAX Forum. All other trademarks are the properties of their respective owners.

## Introduction

The idea of group tests, or more formally known as a Plugfest, is one of several venues used by numerous technology consortiums. The venue is a means for providing vendors the opportunity to address potential ambiguities and to improve the testing scenarios and capabilities in a technology standard.

In the WiMAX Forum, a Plugfest is a one week long event carried out at a WiMAX Forum-contracted testing site to primarily validate and verify the interoperability of a vendor's equipment with other vendors' equipment. A vendor is considered to be interoperable once they have demonstrated that their hardware is able to send and receive packets of data with two other vendors involving base stations and subscriber stations for a selected certification profile. Before the Plugfest venue takes place, participating vendors must agree on a set of RF/PHY characteristics within a given certification profile. In all instances, a minimum of 3 vendors must be available to conduct a suite of selected interoperability testing scenarios within a given certification profile. The WiMAX Forum requires a minimum of 5 to 6 vendors for any Plugfest.

The key objectives of a Plugfest are to:

- Identify where there may be differing standards interpretations that must be resolved
- Identify interoperability problems which may be firmware or software related
- Encourage open and unambiguous technical discussions of the test scenarios and the standard with a means to correct them
- Prepare a vendor to submit their products for formal certification testing
- Continuously improve the quality of interoperability testing to ensure a viable WiMAX Certification process
- Make improvements for implementing future group testing venues

The WiMAX Forum Certification Working Group (CWG) has determined that Plugfest events will be held about every four months at various test laboratories around the world. In some instances we may see additional Plugfests planned to prepare vendors for future certification releases. Typically, these events are posted on the WiMAX Forum Site for the members of the CWG or the Technical Working Group (TWG). The current Plugfest is extraordinary in that we have Bechtel Telecommunications jointly hosting the venue collaborating with Centro de Tecnología de las Comunicaciones, S.A. (CETECOM Labs), and the WiMAX Forum. This is the fifth Plugfest that we have conducted where service flows for Quality of Service (QoS) traffic, network entry procedures, implementation on the classification of data packets for Mobile WiMAX were all achieved as we are in the midst of preparing WiMAX Forum Certification Testing for Wave 1 of Mobile WiMAX. While the focus for this venue was predominantly on Mobile WiMAX, we had several vendors demonstrate interop testing for nomadicity and portability.

This event was organized in the context of a cooperative agreement between Bechtel Telecommunications and the WiMAX Forum signed in June 2006. As the primary host for this first WiMAX Forum Mobile Plugfest, Bechtel will be providing logistical and engineering services. This event is important in that it is also the first WiMAX Plugfest in North America, and is the first Public WiMAX Mobile Plugfest worldwide. Scenarios and profiles for interoperability for this venue were developed jointly by the CWG and TWG for Mobile WiMAX devices. The interop testing scenarios incorporate the IEEE 802.16 and European Telecommunications Standards Institute (ETSI) HiperMAN standards in the joint development of protocol conformance test specifications that are one of the essential elements of the WiMAX Certification program. The Technical Committee BRAN (Broadband Radio Access Networks) is the home to these activities at ETSI where HiperAccess and HiperMAN

standards and WiMAX/HiperMAN test specifications are developed with the extensive support of ETSI's Protocol and Testing Competence Centre (PTCC). Most of the work lends itself to improving interoperability amongst vendors.

This event will greatly contribute to bring Equipment Vendors closer to achieve certification, and is critical to manufacturers, Telecommunication carriers, and service providers.

## WiMAX Forum overview

The WiMAX Forum™ is an industry-led, not-for-profit corporation formed to promote and certify the compatibility and interoperability of Broadband Wireless Access (BWA) products using the IEEE 802.16 and ETSI HiperMAN wireless MAN specifications. The Forum's goal is to accelerate the introduction of these systems into the marketplace. WiMAX Forum Certified™ products will be fully interoperable and are expected to support Broadband Fixed, Portable and Mobile Applications. Through WiMAX Forum-led efforts, the economies of scale made possible by standards-based, interoperable products will drive price and performance levels unachievable by proprietary approaches. As a result, service providers worldwide will be able to deliver economical broadband data, voice and video services to both residential and business customers.

## WiMAX Technology framework

WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. Mobile WiMAX technology enables the mobility features and attributes for the end user. WiMAX will provide fixed, nomadic, portable and mobile wireless broadband connectivity without the need for direct line-of-sight with a base station. In a typical cell radius deployment of three to 10 kilometers, WiMAX Forum Certified™ systems can be expected to deliver capacity of up to 40 Mbps per channel, for fixed and portable access applications. This is enough bandwidth to simultaneously support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. Mobile network deployments are expected to provide up to 15 Mbps of capacity within a typical cell radius deployment of up to three kilometers. The WiMAX chipsets will be incorporated in notebook computers, ultra mobile PCs, PDAs, and handsets, allowing for portable outdoor broadband wireless access for private and public sectors.

## Key elements of WiMAX Technology

One of the main elements of WiMAX technology is the interoperability of WiMAX equipment, certified by the WiMAX Forum, resulting in mass volume and confidence for service providers to buy equipment from more than one company and that everything works together. The WiMAX Forum has brought together leaders in the communications and computing industries to drive a common platform for the global deployment of IP-based broadband wireless services.

The IEEE 802.16 Air Interface Specification contains options for a number of physical layers for different frequency bands and region-by-region frequency regulatory rules. In order to achieve interoperability, WiMAX has undertaken the development of the System Profiles specifying which options to utilize, Testing Specifications to verify these specific profiles, and Certification Labs to permit vendors to prove that their equipment meets these profiles and interoperates.

Other key elements are cost, coverage, capacity and standard for both fixed and mobile wireless access.

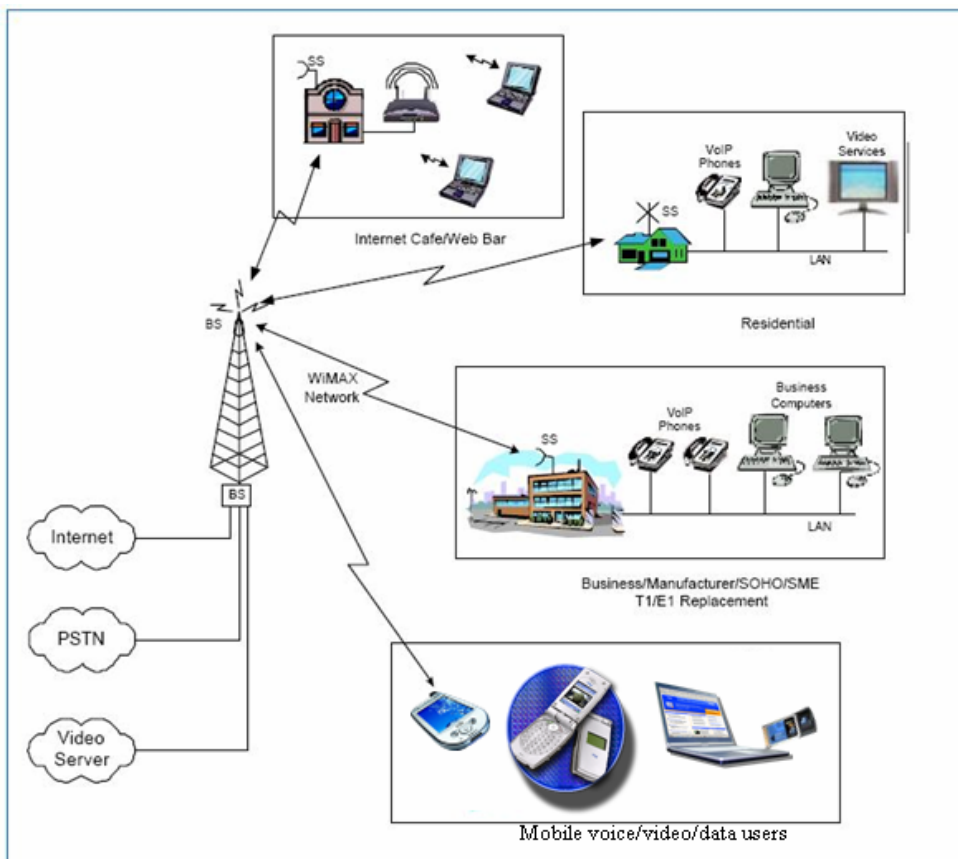


Figure 1: WiMAX Network

## WiMAX Plugfest Testing

### Test architecture

Five system test configurations are defined and used in the WiMAX Mobile Plugfest. A System Under Test (SUT) is defined as a network consisting of one Base Station (BS) and 1 to 3 Mobil Stations (MSs). The system will include, when necessary, monitoring devices such as a WiMAX Protocol Analyzer and/or a Vector Signal Analyzer (VSA). The following specific configurations are used in the Plugfest:

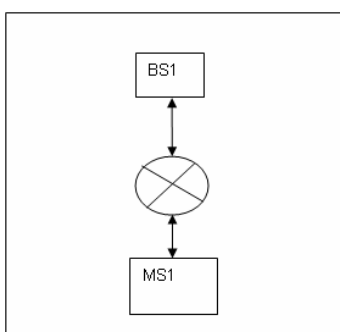
- SUT1: Single BS and Single MS – One Vendor.
- SUT2: Single BS and Single MS – Two Vendors
- SUT3: Single BS and Two MS (from Same Vendor).
- SUT4: Single BS and Two MS (from Different Vendors).
- SUT5: Single BS and Three MS (Three Different Vendors).

Devices in each SUT shall be interconnected by wired means.

QoS testing will be done in terms of interoperability in order to emulate the real final user experience (i.e. transmission of data according to the QoS parameters defined and checking that the QoS of a service flow is not affected by other Best Effort (BE)-type data transmissions).

### SUT #1: Configuration with Single BS and Single MS (One Vendor)

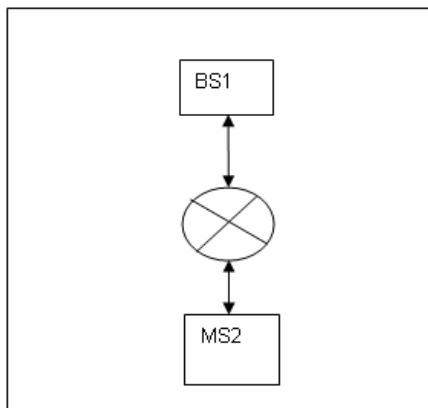
Figure 2 below shows the test configuration in which, a single BS1 is connected to a single MS1. The BS1 and MS1 are from the same vendor. This is generally the initial test configuration for all vendors prior to engaging in interoperability testing to verify the operation of their own equipment. Vendors without both a BS and an MS will not be able to run this test and will move to other testing.



**Figure 2: SUT configuration # 1**

### SUT #2: Configuration with Single BS and Single MS (Two Vendors)

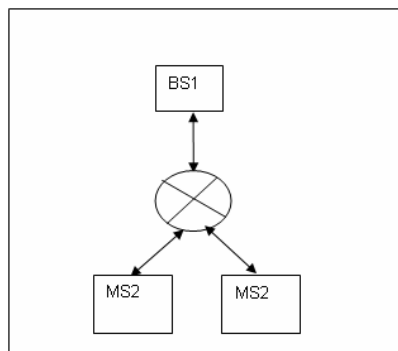
In Figure 3 test configuration, a single BS is connected to a single MS. The BS1 and MS2 are from different vendors. In this SUT test configuration, the BS is transmitting and receiving data packet from a single mobile station (MS1). A monitoring device can be used to capture all the necessary MAC messages and PHY/RF parameters.



**Figure 3: SUT configuration #2**

### SUT #3: Configuration with Single BS and Two MS (from Same Vendor)

Figure 4 shows the SUT test configuration #3. In this SUT test configuration, the BS is transmitting and receiving data packet from two mobile stations. The two MS2s are from the same vendor but different vendor than the BS1.



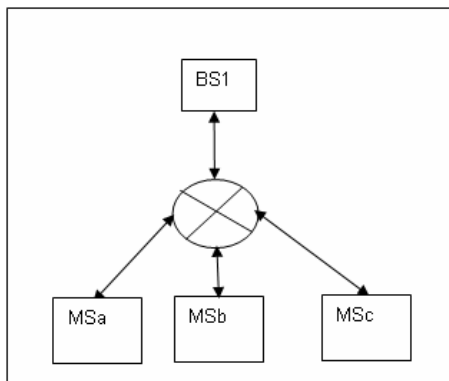
**Figure 4: SUT configuration #3 and #4**

### SUT #4: Configuration with Single BS and Two MS (from Different Vendors)

In this test configuration a single BS1 is connected to two MSs, as shown in Figure 4 (the same Figure as SUT #3). But in this scenario, the two MSs are from the different vendors. One of the MS vendors may also be the BS vendor (as shown) depending on equipment availability. Of course, all three UUT may be from different vendors.

### SUT #5: Single BS and Three MS (Three Different Vendors)

Figure 5 shows the SUT test configuration #5. In this test configuration a single BS is connected to three MSs. Each of the MS's may be from different vendors, or two MS's may be from the same vendor or one of the MS could be from the same BS1 vendor, depending on the testing schedule at the Plugfest.



**Fig. 5: SUT configuration #5**

Certification Profiles tested in this Plugfest consisted of:

- 2.3-2.4 GHz, 5/8.75/10 MHz, TDD
- 2.496-2.69 GHz, 5/10 MHz, TDD
- 3.4-3.6 GHz, 5/7 MHz, TDD
- 4.935 GHz-4.990 GHz, 5 MHz, TDD

## Test Plan

Test scenarios for the WiMAX Plugfest are organized in three different groups in the expected flow described below to achieve exchange of data packet between vendors hardware:

- Network Entry Procedure
- Traffic Connections Establishment
- User Data Transfer

The order of the Scenarios is arranged according to complexity and feasibility. Figure 6 below shows the test sequencing structure for the WiMAX Plugfest.

1 Network Entry Procedure	1.1 MS(s) Synchronize to BS 1.2 Ranging 1.3 Capabilities Negotiation 1.4 Authentication (Not Used) 1.5 Registration
2 Traffic Connections Establishment	2.1 Service Flow Provisioning 2.2 Service Flow Activation
3 User Data Transfer	3.1 Downlink PING 3.2 Uplink PING

**Figure 6: Test scenario structure for WiMAX Mobile 2 Plugfest**

Test scenarios were developed to test each functionality. In order to insure that all the important functionalities needed to achieve interoperability among different vendors devices are considered, a total number of five test scenarios were defined for this WiMAX Mobile Plugfest. The scenarios do not determine if a product conforms to the standard as they are not designed as conformance tests. Rather, they provide one method to isolate and resolve problems within WiMAX capable devices that may impact their ability to interoperate.

As an example, scenario 3 is a Point to Multipoint configuration with a single base station and two mobile stations, as shown in Figure 4. The initial testing is with both MS from the same vendor and the subsequent testing is with the MS1 and MS2 from different vendors. The Network Entry procedure has both MSs executing the Network Entry Procedure Simultaneously. Below are the sequences of test events for Ranging as a part of testing Network Entry Procedure of two MSs executing the procedure simultaneously.

Test Sequence for Ranging

The MSs acquire DL synchronization

The MSs transmit initial CDMA ranging codes according to the UL MAP CDMA allocations.

The BS transmits ranging response to each one of the MSs using their selected CDMA code. The ranging-responses (RNG-RSP) may contain adjustments to values for UL TX power, time and frequency. Details of RNG-RSP are depicted in Figure 7 below.

Parameter Name	Value	Remark
Management Message Type	5	RNG_RSP
Timing Adjustment		
Power Level Adjust		
Offset Frequency Adjust		
Ranging Status	1 or 3	1 = continue, 2 = abort, 3 = success, 4 = re-range
Ranging code attributes		Bits 31:22 - Used to indicate the OFDM time symbol reference that was used to transmit the ranging code. Bits 21:16 - Used to indicate the OFDMA subchannel reference that was used to transmit the ranging code. Bits 15:8 - Used to indicate the ranging code index that was sent by the MS. Bits 7:0 - The 8 least significant bits of the frame number of the OFDMA frame where the MSS sent the ranging code.

**Figure 7. RNG-RSP Contents**

The MSs continue to send ranging code if they receive RNG-RSP messages with the Ranging Status marked as "continue".

When the adjustment is successful, the BS sends a RNG-RSP message with the Ranging Status marked as "success". The BS also allocates Uplink allocation to each one of the MS to transmit Range-Request message, by UIUC14.

The MSs should transmit ranging-request (RNG-REQ) message to the BS specifying their individual MAC address. Content of RNG-REQ is depicted in Figure 8 below.

Parameter Name	Value	Remark
Management Message Type	4	RNG_REQ
Reserved	0	
MAC Version	5	
Requested Downlink Burst Profile	0	
MS MAC address	xyyyxyyyxyy	Each MS sends different MAC Address

**Figure 8. RNG-REQ Contents**

Figure 9 below contains the Ranging-Response (RNG-RSP) that the BS should transmit to the MSs allocating different Basic CID and Primary Management CID to each one of the MSs.

Parameter Name	Value	Remark
Management Message Type	5	RNG_RSP
MS MAC Address		
Basic Management CID		
Primary Management CID		
Ranging Status	1 or 3	1 = continue, 2 = abort, 3 = success

**Figure 9. RNG-RSP Contents**

## Key Learnings, Observations, and Future Work

The certification process is divided into the development of conformance testing and interoperability testing. The Plugfest is a preview of full interoperability testing which allows vendors to get an early look at how well their equipment interoperates.

During the Plugfest held at Bechtel Telecommunications in Frederick, Maryland, the Forum had nineteen vendors along with three test equipment vendors participating. This represents the largest Plugfest in the history of the WiMAX Forum.

The results of any given Plugfest are not published to foster technical discussions in interpreting standards and to resolve any potential ambiguities. However, there are key learning steps that we can take from this very successful Plugfest.

As with all previous Plugfests, the opportunity to work with other vendors in a real-time interoperable environment enabled all participants to improve their products through clarification of specifications. Using either prototypes or planned commercial hardware in this intensive testing environment, vendors carried out objective dialogue about ambiguities and anomalies that led to the development of continuously improving test scenarios. This Plugfest reaffirmed one of the key elements of the WiMAX Forum's charter which is to develop a framework for high performance end-to-end IP network architecture supporting stationary, portable, and mobile usage models.

It is also important to emphasize that one week of interaction with a variety of vendors at a Plugfest can often result in exponential product improvement that would have only been achieved through months of company in-house testing. The value-added experience of a Plugfest can for many vendors bring about an accelerated path to WiMAX Forum product certification that would otherwise have been a much more laborious process.

This Plugfest continued the evolution of WiMAX testing methodology and tools, such as WiMAX device protocols or MAC and PHY uplink and downlink monitoring. Ensuring optimum testing resolved connectivity problems between different vendors which were the ultimate goal of this Plugfest.

Important improvements have been achieved during this Plugfest, both in technical and organizational aspects. On the technical side, the Plugfest results, in terms of interoperability among vendors' devices, are even better than in previous Plugfests. A total of 6 different Certification Profiles comprising MTG and ETG specifications were successfully tested. The technology clearly showed a significant leap ahead in maturity with twelve different BS-MS setups achieving network entry and ping connectivity within the first day of testing. It's important to note that the number of successful connections obtained during the first day of this Plugfest is similar to the results typically obtained after four days of testing in previous Plugfests. Finally, at the end of the third day of testing, ten BS-MS set-ups had achieved video streaming and FTP transfers, and an additional five other BS-MS setups had shown multipoint video streaming.

The dependence from external resources during testing has been minimized compared to previous Plugfests. The participating engineer teams have been able to do all the changes required on their implementations in real time, avoiding any delay in the testing and therefore allowing more effective testing hours. This lessened dependency on external resources led to more focused debriefing meetings at the end of each day. These debriefings enabled expedited agreement on common interpretations and also on those complex issues that will be reported to MTG and ETG for further study and eventual approval.

The Bechtel, CETECOM, and WiMAX Forum logistics teams achieved a high level of cooperative planning on all requirements for this event such as power, Internet, and other

Plugfest support requirements. Underlying all of this was Bechtel's commitment to safety, security, and comfort for all participants.

The following improvements are planned for future sessions:

Due to the increasing number of different devices and profiles supported by the vendors and the specialization required from their engineers, the current number of allowed engineers per vendor will be increased.

Future Plugfests will be held at larger facilities to enable registration of new members that are planning to make WiMAX products.

## Terminology

BE	Best Effort
BS	Base Station
CDMA	Code Division Multiple Access
CWG	Certification Working Group
DL	Downlink
ETG	Evolutionary Task Group
MAC	Media Access Control
MS	Mobile Station
MTG	Mobile Task Group
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PHY	Physical Layer
QoS	Quality of Service
RF	Radio Frequency
RNG-RSP	Ranging Response
MS	Mobile Station
SUT	System Under Test
TDD	Time Division Duplex
TWG	Technical Working Group
UP	Uplink
UUT	Unit Under Test
VoIP	Voice over Internet Protocol
VSA	Vector Signal Analyzer

## Acknowledgments

The WiMAX Forum Certification Working Group would like to acknowledge the support of CETECOM Labs and Bechtel in hosting the Forum's 5<sup>th</sup> WiMAX Plugfest which was the Forum's third Public Plugfest. Much planning and preparation since the Sophia Antipolis, France Plugfest event proved to be instrumental in enabling vendors to participate and test with other vendors demonstrating that interoperability can be achieved. Participating vendors included, Adaptix, Airspan, Alcatel, Altair Semiconductor, Alvarion, Beceem Communications, Intel, M/A-COM, Motorola, Navini Networks, picoChip, POSDATA, Runcom, Samsung, Sequans, and SOMA Networks.

Participating test tool vendors included Invenova, CETECOM Spain, and Rohde & Schwarz.

The WiMAX Forum Certification Working Group would like to extend profound thanks for the valuable technical insights and observations contributed by Esmael Dinan – Bechtel Labs, Jose de La Plaza – CETECOM Labs and Ed Agis – Intel in writing this White Paper for the first public Mobile WiMAX Plugfest.

For more information about WiMAX related technologies, visit the WiMAX Forum's website at [www.wimaxforum.org](http://www.wimaxforum.org).