White Paper

2nd Mobile WiMAX PlugFest

February 11 – 17, 2007

Malaga, Spain

Hosted by: AT4 wireless

In collaboration with The WiMAX Forum®

Table of Contents

Introduction

The idea of group tests, 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. For this PlugFest, a large number of new test scenarios were developed. Two different concepts of interoperability between equipment were defined:

Basic interoperability where a Base Station and a Mobile Station must interoperate with one another.

Extended interoperability where a Base Station and one or more Mobile Stations interoperate supporting advanced test scenarios (i.e. Power Control, Sleep Mode, Idle Mode, Handover, etc.)

For each concept of interoperability, a vendor is considered to be interoperable once they have demonstrated that their hardware is able to work properly with two other vendors involving base stations and mobile stations for a selected certification profile. Before the PlugFest 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. Formerly, the requirement by the WiMAX Forum to have a minimum of 5 to 6 vendors participate in a PlugFest is no longer necessary as the number of vendor companies participating in these venues has grown rapidly with over 20 equipment vendors registering for the 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) manages PlugFests, which it holds about every four months at various locations around the world. These events have typically been located in testing laboratories. With the onset of increased vendor participation, the events are now held in hotel ballrooms. The 2nd Mobile PlugFest in Malaga, Spain is the WiMAX Forum's largest group test activity in its history with 25 equipment and 10 test equipment vendors participating in the event over a week in duration. During the PlugFest a number of new test scenarios were introduced to cover feature sets such as Fast-Feedback, HARQ (Hybrid Automatic Repeat Request), MAC-level ARQ, Open Loop Power Control, Closed Loop Power Control, PKMv2 (Privacy Key Management version 2), Sleep Mode, Idle Mode, ERT-VR (Extended Real Time Variable Rate Service), Handover, MIMO (Multiple In Multiple Out), and Beamforming for the equipment vendors to try out. Utilizing a total of 16 different test scenarios, participating vendors were given ample opportunities to facilitate the WiMAX Forum's progress towards the beginning of Certification Testing for Wave 1 of Mobile WiMAX.

This 2nd Mobile PlugFest was organized in the context of a cooperative agreement between AT4 wireless and the WiMAX Forum. This event is important in that it is also the first public Mobile WiMAX PlugFest in Europe. Scenarios and profiles for interoperability for this venue were developed jointly by the CWG and Technical Working Group (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 Forum 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), dedicated to improving interoperability amongst vendors.

Overall, this PlugFest continues to enable Equipment Vendors in their pursuit of Mobile certification for their products by a WiMAX Forum® Designated Certification Laboratory (WFDCL).

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.

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™ technology 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. WiMAX™ chipsets will be incorporated into 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 that results in mass volume and confidence by service providers in the interoperability of equipment from various companies. 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, the WiMAX Forum 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 of deployment, coverage, capacity and standard for both fixed and mobile wireless access.

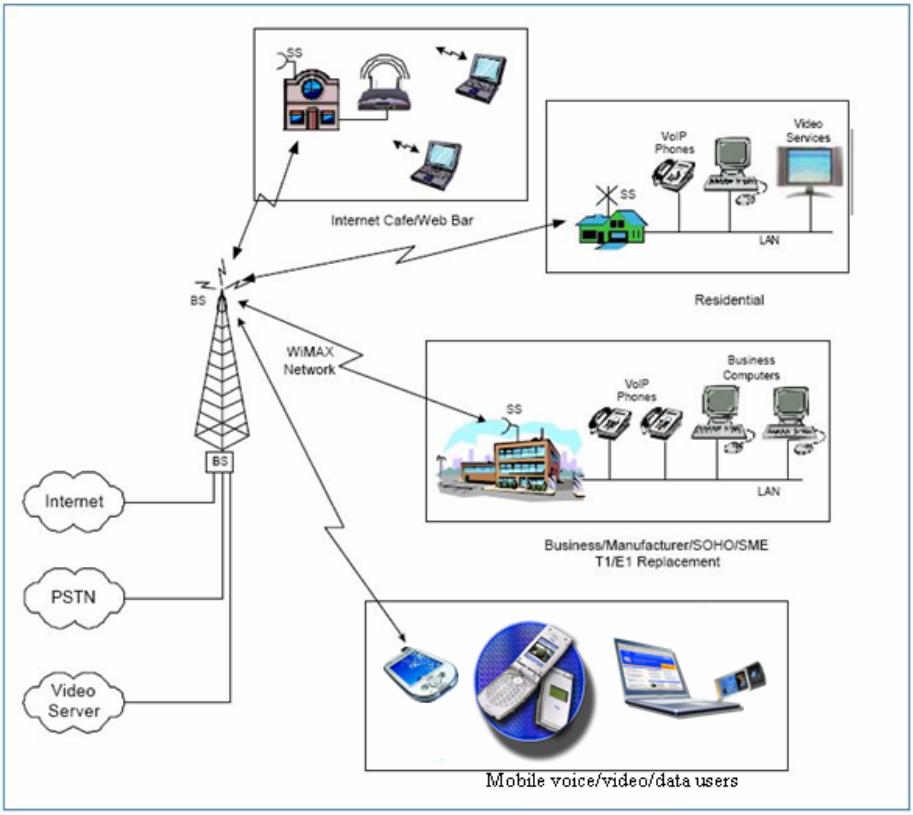

Figure 1: WiMAX™ Network

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 Mobile Stations (MSs). The system will include, when necessary, monitoring devices 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).

SUT6: Two BS and Single MS

Devices in each SUT shall be interconnected by wired means.

QoS testing is 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.

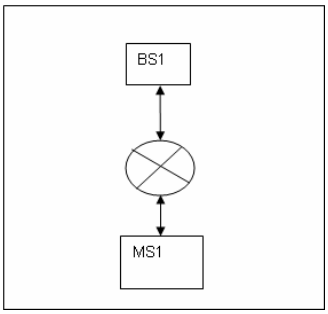

Figure 2: SUT configuration # 1

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.

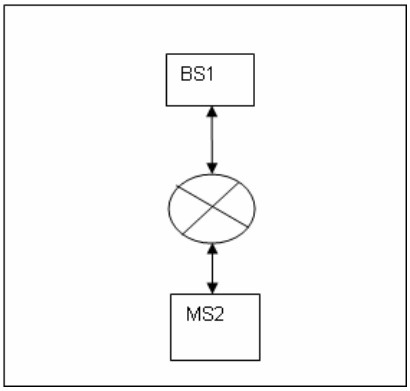

Figure 3: SUT configuration #2

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.

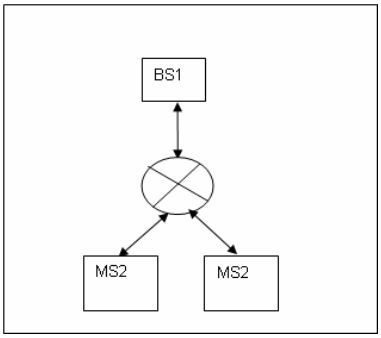

Figure 4: SUT configuration #3 and #4

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.

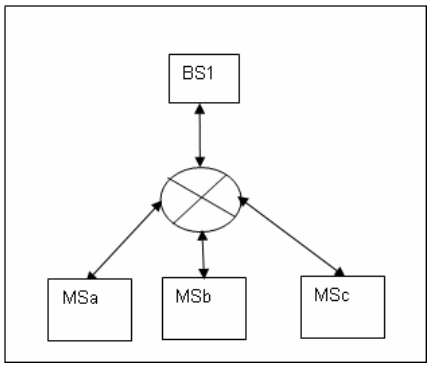

Fig. 5: SUT configuration #5

SUT #6: Two BS and Single MS

This is the SUT employed for running the Handover test scenario. In Figure 6 a single MS unit is connected to two BS units. Both BS units shall be from the same vendor, and may be different sectors on the same station. The MS unit may be from any MS vendor (a), and the setup shall be validated with a MS unit provided or recommended by vendor 1. Handover will be effected by sequentially adding attenuation to the RF links to decrease the signal strength and imbalance the signals received by the BS unit.

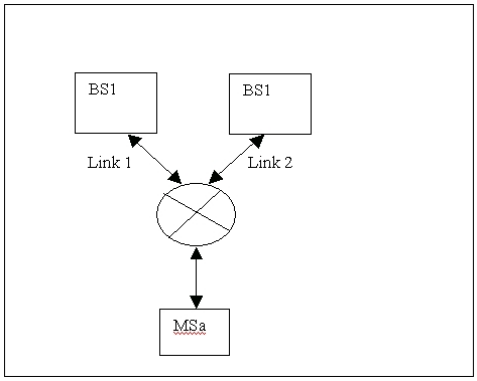

Fig. 5: SUT configuration #5

Below are the certification profiles the vendors tested in the 2nd WiMAX Mobile PlugFest

Band Class Index	Frequency Range	Channel Bandwidth(s)	FFT Size
1A	2.3-2.4 GHz	8.75 MHz	1024
1B	2.3-2.4 GHz	5 MHz/10 MHz	512/1024
3A	2.496-2.69 GHz	5 MHz/10 MHz	512/1024
5A	3.4-3.8 GHz	5 MHz	512
5B	3.4-3.8 GHz	7 MHz	1024
5AL	3.4-3.6 GHz	5 MHz	512
5BL	3.4-3.6 GHz	7 MHz	1024

Test Plan

Test cases for the WiMAX Forum PlugFest are organized in a series of test scenarios checking a wide range of Mobile WiMAX™ functionalities, such as Fast-Feedback, HARQ, MAC-level ARQ, Open and Closed Loop Power Control, PKMv2, Sleep Mode, Idle Mode, ERT-VR, Handover, MIMO and Beamforming

Table 1 below shows the test suite structure for the WiMAX PlugFest.

Scenario 1a – Basic Configuration

Network Entry Procedure: Synchronization, Initial Ranging, Capabilities Negotiation, Registration.

Traffic Connections Establishment: Service Flow Provisioning, Service Flow Activation.

User Data Transmission: Downlink, Uplink.

Scenario 1b – Fast Feedback

Network Entry: Synchronization, Initial Ranging, Capabilities Negotiation (w/ Fast Feedback and Physical CINR support), Registration.

CINR Reporting in Fast-Feedback Channel.

Scenario 1c – HARQ

Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation (w/ HARQ with chase combining on DL and UL), Registration.

DL and UL HARQ functionalities.

Scenario 1d – MAC-level ARQ

Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration (w/ ARQ support)

UL and UL ARQ functionalities.

Scenario 1e – Power Control

Open Loop Power Control: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation (w/ Uplink Power Control support set to Open Loop Power Control), Registration, Switch to Open Loop Power Control Open Loop Power Control functionality.

Closed Loop Power Control: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration, Closed Loop Power Control functionality.

Power Control in Ranging Mode: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration, Periodic Ranging

Scenario 1f – Security

Network Entry w/ PKMv2 enabled: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation (w/ PKMv2 support), EAP Initial Authentication, SA-TEK exchange, Registration.

Traffic Connections Establishment: Service Flow Provisioning, Service Flow Activation.

User Encrypted Data Transmission: Downlink, Uplink.

Scenario 1g – Sleep Mode

Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration (w/ sleep mode support).

Power Saving Class Activation/Deactivation.

Scenario 1g – Idle Mode

Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration (w/ idle mode support).

BS Initiated Idle Mode, MS Initiated Idle Mode, MS Paging for DL transmissions.

Scenario 1i – ertPS

Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration.

ertPS Service Flow Provisioning and Activation.

User Data Transmission: Downlink, Uplink.

Scenario 1j – Simple Handover

1. Network Entry: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration (w/ handover support)
2. Handover.

3. DL/UL user data transmission.

Scenario 1k – MIMO

1. Basic MIMO: Capabilities Negotiation (w/ MIMO support), Registration, Service Flow Provisioning and Activation, DL/UL user data transmission.

2. Collaborative MIMO: Capabilities Negotiation (w/ MIMO support), Registration, Service Flow Provisioning and Activation, DL/UL user data transmission.

Scenario 1l – Beamforming

1. DL/UL user data transmission (BS sends PUSC w/ dedicated pilots)

2. DL/UL user data transmission (BS sends AMC w/ dedicated pilots)

3. UL user data transmission in PUSC w/ channel rotation disabled.

4. UL user data transmission in PUSC w/ channel rotation enabled.

Scenario 2 – P2MP Configuration
MS1: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration, Service Flow Provisioning/Activation, DL/UL data transmission.

MS2: MS-BS Synchronization, Initial Ranging, Capabilities Negotiation, Registration, Service Flow Provisioning/Activation, DL/UL data transmission.

Scenario 3 – P2MP Configuration with Different Modulation
1. DL/UL user data transmission with different modulations.

2. DL/UL user data transmission with classification rules.

Scenario 4 – P2MP Configuration with QoS
1. DL/UL user data transmission with different MIRs.

Scenario 5 – P2MP Configuration with different MIR
1. DL/UL user data transmission over 2 BE service flows with different MIRs.

2. DL/UL user data transmission over 1 BE and 1 UGS service flows.

Table 1: Test suite structure for2nd Mobile WiMAX 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 Mobile 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 as shown in Figure 6 below starts with the MSs acquiring DL synchronization

The MSs then transmits 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 Range-Responses may contain adjustments to values for UL TX power, time and frequency.

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 sub channel 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 6. Test Sequence for Ranging

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 UlUC14.

The MSs should transmit ranging request message to the BS specifying their individual MAC address.

Figure 7. below shows the RNG-REQ Contents used for PlugFest testing.

Parameter Name	Value	Remark
Management Message Type	4	RNG_REQ
Reserved	0	

MAC Version	5	
Requested Downlink Burst Profile	0	
MS MAC address	xxyyxxyyxxyy	Each MS sends different MAC Address

The BS should transmit ranging response to the MSs allocating different Basic CID and Primary Management CID to each one of the MSs.

The sequencing of the ranging response is shown in figure 8 below.

Figure 8. RNG-RSP Contents

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

Key Learnings, Observations, and Future Work

During the 2nd Mobile PlugFest held at in Malaga, Spain, the WiMAX Forum had a total of 35 equipment and test vendors and 160 engineers participating representing the WiMAX Forum's largest PlugFest event to date.

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. 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 and to dramatically facilitate their way to the WiMAX certification.

For the test systems vendors the PlugFest is a unique opportunity to fine tune their systems and to collaborate in a real testing environment with their potential customers.

For both the WiMAX forum and AT4 Wireless as the lead lab, the PlugFest is the right place to identify and promote the discussion of different interpretations of the standards and the test specifications and to resolve any potential ambiguities. The conclusions will become valuable feedback for the different WiMAX Forum working groups.

The specific test results of any given PlugFest are not published. However, there are key points that we can take from this very successful PlugFest:

In terms of interoperability among vendors' devices, more than 60 different BS-MS setups Interoperated successfully in the PlugFest advanced scenarios compared to 12 successful BS- MS setups for the first Mobile WiMAX™ PlugFest. Also handover was successfully tested in a good number of set-ups proving that the technology clearly showed a significant leap ahead in maturity.

The interoperability testing specifications, which are currently under development, were discussed during the PlugFest. This specification document defines the interoperability testing required for WiMAX certification and its approach was successfully verified using this real test environment.

Related to logistics there are also some important improvements that were included for the first time in this PlugFest. This is the first WiMAX PlugFest that took place in a hotel ballroom. It proved to be very convenient for the attendees, who avoided a commute to the laboratory in order to participate in the event. On the other hand, the adaptation of a hotel ballroom was a new challenge for the WiMAX Forum and AT4 Wireless logistic teams in terms of power network and technical requirements. Due to the increased number of attendees, the room size for this PlugFest was 580 square meters, almost double size of the room for the first mobile PlugFest in September 2006.

Also, new tools were introduced in this PlugFest, such as new templates and forms to help the participants and organizations keep track of the testing schedule and results and to facilitate the samples configuration. All this documentation, together with the documents that are relevant for the PlugFest, were made available via a new FTP server within the PlugFest internal network. This FTP server provided a powerful communications tool among the PlugFest attendees.

The larger number of attendees per company enabled vendor engineering teams to work rapidly, thus there was less waiting time for the vendors to improve their implementations and more time available for testing.

The following improvements are planned for future sessions:

- The tested scenarios are clearly more complex than the ones tested in the previous mobile PlugFest. For that reason, it takes more time for the vendors to achieve the interoperability goals and, therefore, more testing time, or more testing in parallel, will be required for the next PlugFest. In order to do this, options like increasing the number of days for the PlugFest, as well as requiring more hardware, will be considered.

- Due to the different availability and physical characteristics of BSs and MSs the testing scheduling method will be modified for the next PlugFest. The number of testing opportunities, information to the attendees and schedule visibility will be improved while keeping the same level of flexibility and fairness of the method used until today.

- Vendors must commit to remain at the test lab throughout the entire session to ensure that their departure does not impact other participants in achieving their key objectives. A premature departure particularly impacts those vendors who are close to submitting a product for formal certification testing.

Terminology

BE	Best Effort
BS	Base Station
CDMA	Code Division Multiple Access
CWG	Certification Working Group
DL	Downlink
ertPS	Enhanced Real Time Polling Service
FTP	File Transfer Protocol
MAC	Media Access Control
MIMO	Multiple In Multiple Out
MIR	Maximum Information Rate
MS	Mobile Station
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
P2MP	Point to Multipoint
PHY	Physical Layer
QoS	Quality of Service
RF	Radio Frequency
RNG-REQ	Ranging Request
RNG-RSP	Ranging Response
MS	Mobile Station
SUT	System Under Test
TDD	Time Division Duplex
TWG	Technical Working Group
UL	Uplink

UIUC	**Uplink Interval Usage Code**
UUT	**Unit Under Test**
VoIP	**Voice over Internet Protocol**
VSA	**Vector Signal Analyzer**
WFDCL	**WiMAX Forum Designated Certification Laboratory**

Acknowledgments

The WiMAX Forum Certification Working Group would like to acknowledge the support of AT4 Wireless in hosting the Forum's 2nd Mobile WiMAX™ Public PlugFest. Much planning and preparation since the Frederick, Maryland PlugFest event proved to be instrumental in enabling vendors to test with other vendors and to achieve interoperability with even more sophisticated testing scenarios. Participating equipment vendors included Accton Technology Corporation, Adaptix, Airspan Networks, Alcatel-Lucent, Alvarion, Aperto Networks, Beceem, GCT Semiconductor, Inc., Huawei Technologies, Intel Corporation, LG Electronics, Motorola, Navini, Nokia, PicoChip, POSDATA, Redline Communications, Redpine Signals, Runcom Technologies Ltd., Samsung, SEQUANS Communications, SOMA Networks, Telsima, Wavesat Wireless Inc., and ZTE Corporation.

Participating test equipment vendors included, Aeroflex, Agilent, Anite Telecom Ltd., Anritsu Limited, AT4 Wireless, Azimuth Systems, Innowireless, Sanjole, Rohde & Schwarz, and Tektronix.

The WiMAX Forum Certification Working Group would like to extend profound thanks for the valuable technical insights and observations contributed by Ed Agis, Intel, José de la Plaza and Héctor Alba , AT4 wireless, and Steve Heck, WiMAX Forum, for writing this White Paper for the second public Mobile WiMAX™ PlugFest.

For more information about WiMAX™ related technologies, visit the WiMAX Forum's website at www.wimaxforum.org.