WiMAX and IMT-2000

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1.0 Introduction

The inclusion of mobile WiMAX under the IMT-2000 umbrella will offer significant benefits to the mobile community by assuring the global delivery of Wireless Broadband Internet services at the lowest cost. Mobile WiMAX is based upon Orthogonal Frequency Division Multiple Access (OFDMA), an access technology standardized in the IEEE 802.16e-2005 amendment to IEEE STD 802.16. The OFDMA technology has become commonly accepted as the basis for the evolution of mobile technology towards 4G, as it can provide high data rate capability and excellent support for new features such as advanced antenna technologies to maximize coverage and the number of users supported by the network. OFDMA (specifically, the air interface designated "WirelessMAN-OFDMA" within IEEE STD 802.16) provides multipath and interference tolerance in non-line of sight (non-LOS) conditions to achieve ubiquitous broadband coverage in a wide range of operating environments and usage models, including full mobility.

The European Commission and other organizations are pursuing efforts to clarify what is meant by technical neutrality. Recent thinking is that the Radio Transmission Technology (RTT) should be tailored to a specific spectrum assignment to meet certain market and technical criteria as defined by local regulators but not to assume that all RTTs will be acceptable. The WiMAX Forum believes that WiMAX is a favorable technology along with other radio technologies that regulators determine to be appropriate. The WiMAX Forum's position is that regulators and government administrations must assure that, for any spectrum assignment, the most desirable radio technologies should be available to operators for the delivery of Mobile Internet services.

There is a solid basis therefore, to support the argument that mobile WiMAX should be included within the IMT family of radio interface technologies. Embracing this approach will ensure that operators have access to the wireless technologies necessary to meet their long term capacity and business plan requirements. This paper will describe mobile WiMAX and lay out arguments to support the inclusion of mobile WiMAX in revision 7 of Recommendation ITU-R M.1457.

2.0 Mobile WiMAX Overview

The IEEE 802.16 Air Interface Standard is currently the only globally approved standard that delivers OFDMA technology. Mobile WiMAX [Ref.1] is based on the IEEE 802.16e-2005 amendment to IEEE STD 802.16, the most recent revision of which is IEEE STD 802.16-2004 [Ref. 2]. Since that revision, the IEEE 802.16e amendment [Ref. 3], approved by the IEEE in December 2005, enhances the WirelessMAN-OFDMA air interface to provide support for mobile terminals. Specifically, it defines key features necessary for delivering mobile broadband services at vehicular speeds greater than 120 km/hr[1] while maintaining QoS comparable to broadband wireline access alternatives.

These features and attributes include:

- Tolerance to Multipath and Self-Interference with subchannel orthogonality in both the downlink (DL) and uplink (UL) directions.
- Scalable Channel Bandwidths from 1.25 to 20 MHz[2] with a corresponding choice of Fast Fourier Transform (FFT) size.
- Time Division Duplex[3] (TDD) is defined for the initial mobile WiMAX profiles due to its added efficiency in support of asymmetric traffic and its channel reciprocity for effective support of advanced antenna systems.
- Hybrid-Automatic Repeat Request (H-ARQ) to provide added robustness with rapidly changing path conditions in high mobility situations.
- Frequency Selective Scheduling and subchannelization with multiple permutation options to provide mobile WiMAX the ability to optimize connection quality based on relative signal strengths on a connection-by-connection basis.

[1] Evolution to higher vehicular speeds will be considered if required for specific applications. A usage model requiring a broadband wireless connection to a high speed commuter train for example is an application that may require support for higher vehicular speeds.

[2] Release-1 system profiles, approved in early 2006, include channel bandwidths of 5, 7, 8.75, and 10 MHz. Other channel bandwidths will be considered in future profiles as required to address specific market opportunities or local spectrum regulations.

[3] Although TDD is preferable for broadband data-centric services, FDD is supported in the standard and will be considered in future mobile WiMAX profiles as required to address specific market opportunities or local spectrum regulations.

- Power Conservation Management to ensure power-efficient operation of battery-operated mobile handheld and portable devices in Sleep and Idle modes.
- Network-Optimized Hard Handoff (HHO) is supported to minimize overhead and achieve a handoff delay of less than 50 milliseconds.
- Multicast and Broadcast Service (MBS) combines the features of DVB-H and 3GPP E-UTRA for:
    a) High data rate and coverage using a Single Frequency Network
    b) Flexible radio resource allocation
    c) Low mobile device power consumption
    d) Low channel switching time
- Advanced Antenna System (AAS) support aided by subchannelization and channel reciprocity enables a wide range of advanced antenna systems including MIMO, Beamforming, space-time coding (STC) and spatial multiplexing (SM).
- Fractional Frequency Reuse controls co-channel interference (CCI) to support universal frequency reuse with minimal degradation in spectral efficiency.
- 5 millisecond Frame Size provides optimal tradeoff between overhead and latency.

An evaluation of mobile WiMAX performance based on the 1xEV-DV evaluation methodology [Ref. 4] predicts net downlink sector throughput for a 10 MHz channel bandwidth to be greater than 13 Mbits/sec for a DL to UL traffic ratio equal to 3:1 [Ref. 5]. With this throughput performance and the aforementioned features and attributes, mobile WiMAX can cost-effectively deliver:

- Broadband value-added services including, data, and video services as well as VoIP
- Support for fixed, nomadic, portable, and mobile usage models
- Ubiquitous coverage in non-LOS conditions in a wide range of demographic environments

Major operators have already announced plans to deploy mobile WiMAX[4,5] systems based on WirelessMAN-OFDMA and, services based on mobile WiMAX-based systems,

[4] "Sprint Nextel Selects WiMAX as Next Generation 4G Technology Platform", Press release, Aug. 8, 2006

[5] "Sprint Bets on New Wireless 'WiMax'", Wall Street Journal, Aug. 8, 2006, article also mentions ATT and Clearwire.

branded as WiBro services, were launched in Korea in the 2.3-2.4 GHz band in mid-2006. The timeline for WiMAX products based on OFDMA is summarized in Table 1.

	2005	2006	2007
802-16e-2005 Amendment Ratified	▲		
Mobile WiMAX Rel-1 System Profiles Approved		▲	
Mobile WiMAX Rel-1 Certification Profiles		▲	
2nd Certification Lab Opens (TTA Labs)		▲	
WiBro Service Launch in Korea		▲	
3rd Certification Lab Opens (CATR)		▲	
Mobile WiMAX-Certification Wave 1 Products Available			▲
Mobile WiMAX-Certification Wave 2 Products Available			▲

Table 1: WiMAX Timeline

Approved Release-1 system profiles for mobile WiMAX [Ref. 5] cover spectrum ranging from 2.3 to 2.7 GHz and 3.3 to 3.8 GHz. All currently approved system profiles are based on time division duplex (TDD). The 2.3 to 2.7 GHz band covers spectrum allocated for WiBro services in Korea as well as the 2.5 to 2.7 GHz band, a band identified for IMT-2000[6] that will have wide applicability worldwide.

Certification testing for mobile WiMAX products will begin in the first half of 2007 with Certification "Wave 1" testing. Subsequently, additional certification tests will be implemented to certify additional WiMAX-supported features. Certification "Wave 2" testing will begin in the second half of 2007 and will include key advanced features such as MIMO and Beamforming. These and other added features improve link margins,

[6] ITU Radio Regulations Footnote 5.384A, "The bands, or portions of the bands, 1710-1885 MHz and 2500-2690 MHz, are identified for use by those administrations wishing to implement International Mobile Telecommunications-2000 (IMT-2000) in accordance with Resolution 223 (WRC-2000). This identification does not preclude the use of these bands by any other applications of the services to which they are allocated and does not establish priority in the Radio Regulations."

channel throughput, and add other enhancements to support additional broadband services.

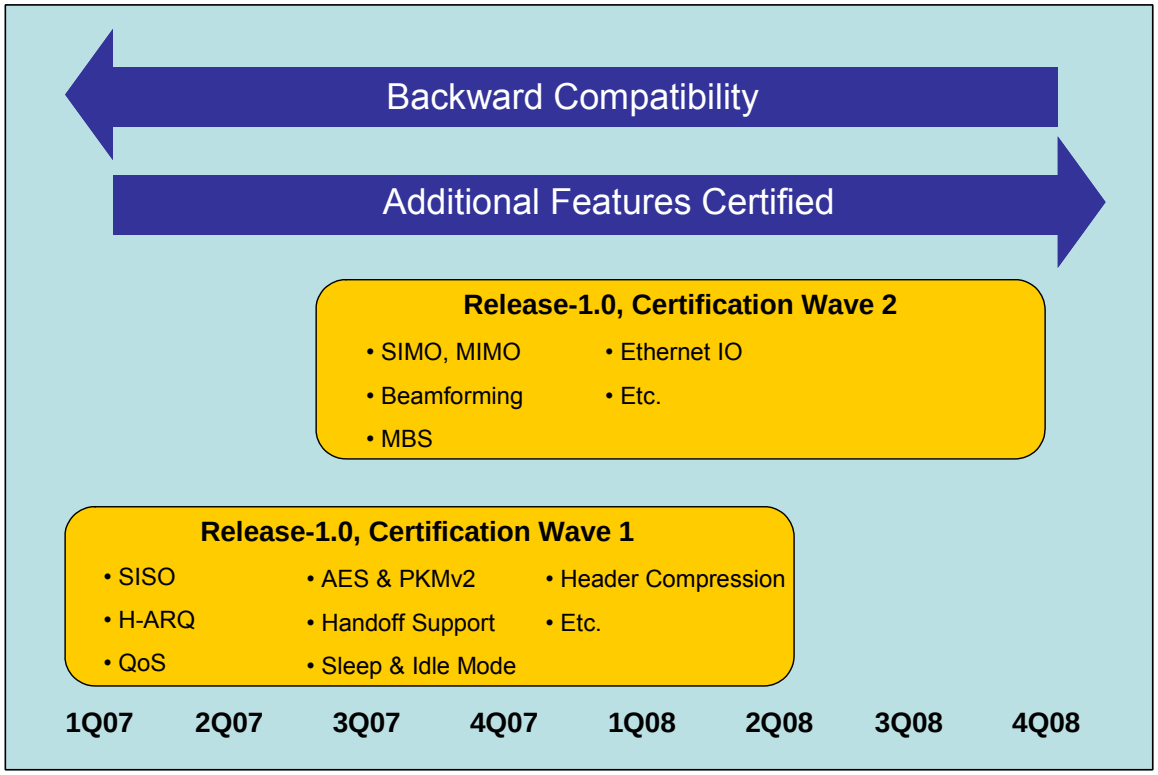

Figure 1: Certification "Wave 1" and Certification "Wave 2" Features

3.0 Mobile WiMAX and IMT-2000

The ITU developed IMT-2000 to harmonize 3G mobile systems and help prevent fragmentation and increase opportunities for worldwide interoperability. As defined by ITU Rec. M.1457-6, IMT-2000 currently supports five radio interfaces and three different access technologies, using FDMA, TDMA, and CDMA. These radio interfaces are:

- CDMA-Direct Spread (Universal Terrestrial Radio Access-UTRA, also known as W-CDMA)
- CDMA-Multi Carrier (CDMA2000)
- CDMA TDD (UTRA TDD)

- TDMA Single Carrier [UWC (Universal Wireless Communication)-136]
- FDMA/TDMA (Digital Enhanced Cordless Communications-DECT)

Although mobile WiMAX is not currently a part of the IMT-2000 definition of 3G, there is no question that the technologies inherent in WiMAX will be an integral part of future mobile systems in the move towards greater data handling capability without sacrificing mobility and portability. It is widely accepted that next generation mobile systems will be based on OFDMA; indeed, evolutions of 3G currently in development, such as 3GPP's ongoing Long-Term Evolution (LTE) project plans to incorporate OFDMA[7]. Meanwhile, OFDMA has already been adopted as the basis of mobile WiMAX. OFDMA inherently provides excellent support for advanced antenna technologies, such as MIMO, STC, and Beamforming that are essential to meet LTE and Next Generation performance goals. LTE is also migrating away from a circuit-switched network to an all-IP network, which is expected to be the core of IMT-Advanced. All of these capabilities are currently built into mobile WiMAX based on the IEEE 802.16 air interface standard. These factors clearly establish a sound basis for adding mobile WiMAX to the IMT-2000 family of supported radio interfaces in ITU Rec. M.1457, beginning with the next revision, M.1457-7.

In November 2006, the IEEE contributed a proposal to ITU-R WP8F (contribution ITU-R WP/1065) to add a new radio interface, designated as IP-OFDMA and based on a specific case of IEEE 802.16, to ITU-R M.1457. IP-OFDMA is consistent with the current mobile WiMAX Release-1 profiles, specifying TDD with 5 and 10 MHz channel bandwidths. In December 2006 the WiMAX Forum submitted a supporting contribution to ITU-R WP8F (contribution ITU-R WP/1079) titled “Additional Technical Details Supporting IP-OFDMA as an IMT-2000 Terrestrial Radio Interface”.

3.1 Benefits of Including IP-OFDMA within IMT-2000

The IEEE'S IP-OFDMA proposal is based upon Orthogonal Frequency Division Multiple Access technology and a packet-oriented network. This is clearly the direction in which mobile technology is evolving. Supporting IP-OFDMA in the IMT-2000 family enables significant flexibility in network deployment options and service offerings. For example, service providers can provide access in low density environments or enhance access capacity in metropolitan and suburban areas to support value-added services. The inclusion of this additional radio interface would provide added value by giving service providers additional flexibility in selecting an IMT-2000 technology for a more optimal

[7] OFDMA is currently included in the downlink specification for LTE

fit to their business model, and a more logical stepping stone to the delivery of Next Generation Mobile Internet services.

IEEE 802.16 was designed from the ground up to support an all-IP technology optimized for high-throughput, real-time data applications and not constrained to a legacy infrastructure. It is based on a next-generation advanced all-IP core network, which includes interworking with IP Multimedia Subsystem (IMS)[8] to facilitate a rapid, low cost, rollout of new applications and interworking with 2G, 3G and IP-based technologies. In addition, WiMAX fully supports 3GPP2's counterpart, Multi-Media Domain (MMD); emerging architectures that will enable service providers to rapidly introduce a wide range of rich voice and data applications at low incremental cost. With IMS and MMD, service providers can develop applications independently of the access technology within a flexible layered architecture in which application modules can be easily modified or reused.

Mobile WiMAX offers low latency, advanced security, QoS (Quality of Service), and, with appropriate spectrum harmonization, worldwide roaming capability. The WiMAX Forum Global Roaming Working Group expects to announce a specification and business model to assure "Roaming" within WiMAX as well as other networks designated in IMT-2000. Service providers also benefit from open global standards that foster vendor interoperability and lower equipment costs.

Service providers expend considerable time and resources in evaluating whether new technologies offer additional value before making deployment commitments. Although IEEE 802.16e-2005 has existed as an approved standard only since December 2005, several major deployments have already been launched or announced. For example, Korea Telecom and SK Telecom have already deployed Mobile WiMAX in Korea in the 2.3–2.4 GHz band. Operators such as Sprint-Nextel, Clearwire, AT&T, and NextWave Broadband have announced their intention to deploy Mobile WiMAX in the United States. The WiMAX Forum also expects a significant number of additional operators to publicly announce Mobile WiMAX deployments in 2007. The fact that a full third of the WiMAX Forum member companies are service providers is indicative of their widespread support and the value that they perceive WiMAX as bringing to their business operations and future plans. As stated above, the WiMAX Forum has taken a proactive role in ensuring that mobile WiMAX will be capable of interworking with

[8] The WiMAX Forum does not foresee a need to modify the IMS specification defined within 3GPP, as the 3GPP SA has already approved WiMAX as a non-3GPP technology for interworking. See TS#1: SAE for LTE and TS#2: SAE for non-3GPP access (i.e. WiMAX).

existing 3G networks and supporting emerging architectures, like IMS, to enable operators to make the same applications and services available across multiple wired and wireless interfaces.

It is important to note that operators in developing countries are also interested in deploying broadband solutions based upon mobile WiMAX. Operators in these countries have demonstrated that they see the value in this technology and believe it is well suited to their business models and deployment requirements.

Including IP-OFDMA within the IMT-2000 family of radio transmission technologies will put mobile WiMAX on a comparable worldwide footing with EV-DO, HSPA, and other recent and planned enhancements to 3G technology. This will offer operators an additional migration path to consider as they strive to add network capabilities to support a larger suite of value-added broadband services.

4.0 Mobile WiMAX Long-Term Vision

Whereas mobile WiMAX has evolved from a broadband data-centric vision, other mobile cellular technologies have evolved from an initial focus on voice services. Although the initial drivers differ, as illustrated in Figure 2, there is a growing convergence as WiMAX technology pushes for greater mobility and terminal portability and mobile operators push for more value-added services requiring higher data rates. As this trend continues there will be less and less to distinguish between these two technologies which arise from two fundamentally different backgrounds.

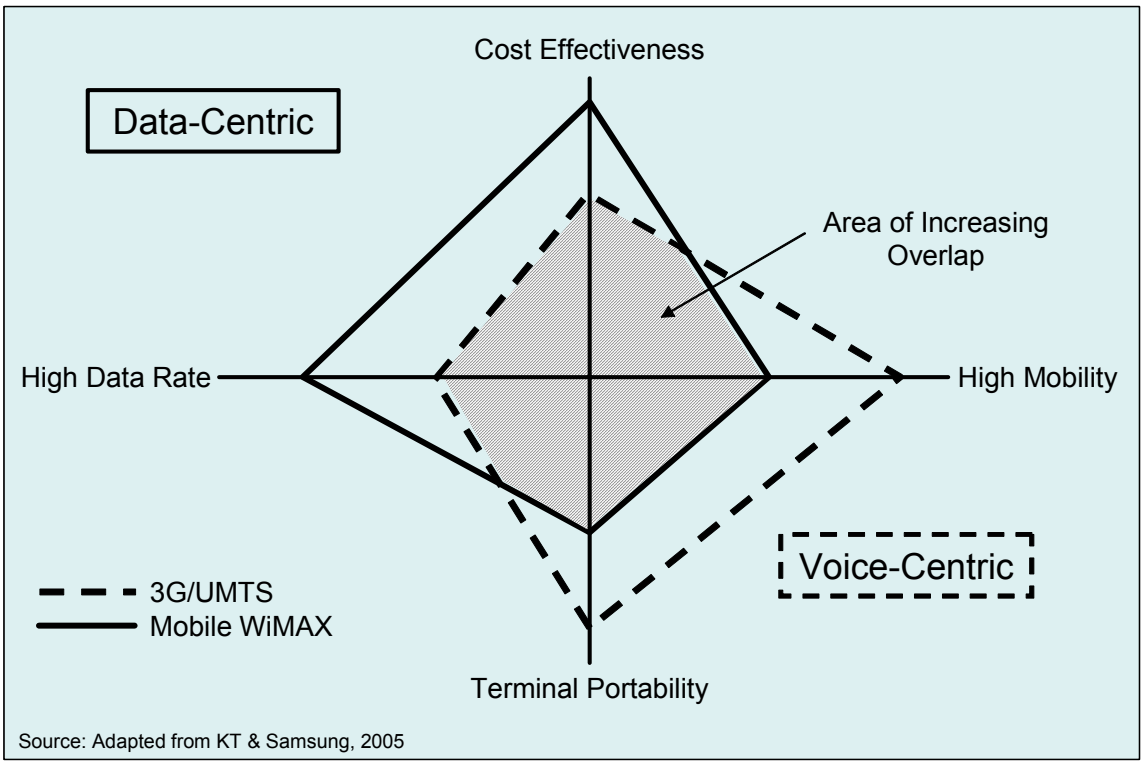

Figure 2: Varied Approaches to Personal Broadband

In the near term, mobile WiMAX will continue to evolve, as additional system profiles and features are defined by the WiMAX Forum to address specific market requirements and opportunities. These will be added features and capabilities that are currently supported by IEEE STD 802.16 but not included in the Release-1 system profiles.

The long term evolution of WiMAX is expected to track further enhancements to the IEEE 802.16 standard. Numerous enhancement projects are underway in the 802.16 Working Group, and a more ambitious undertaking is planned in the IEEE 802.16m amendment project which, when chartered, would target future systems beyond IMT-2000 known as IMT-Advanced. The WiMAX Forum considers IEEE 802.16m as the vehicle to support convergence of WiMAX and other mobile technologies.

5.0 Mobile WiMAX and IMT-Advanced

IMT-Advanced, also known as "systems beyond IMT-2000" is envisioned to provide even higher data rates with high mobility to satisfy an expected growing need for broadband mobile services that goes beyond what IMT-2000 can provide. IMT-

Advanced anticipates technologies that will be required 3 to 5 years into the future with target peak data rates, for research and investigation, of up to 100 Mbits/sec in high mobility applications and up to 1 Gbit/sec in low mobility or nomadic applications. The capability proposed by IMT-Advanced is often referred to as "4G." It is widely accepted that OFDMA technology will be included in IMT-Advanced.

IMT-Advanced is a long term endeavor. The full criteria, being developed within ITU-R Working Party 8F, are not expected until 2008. The specification of IMT-Advanced technologies will probably not be completed until at least 2010. In preparation for IMT-Advanced, the IEEE 802.16 Working Group has moved to initiate a new project designated as "802.16m" with the intent of developing enhancements to IEEE STD 802.16 to ensure suitability as an IMT-Advanced proposal.

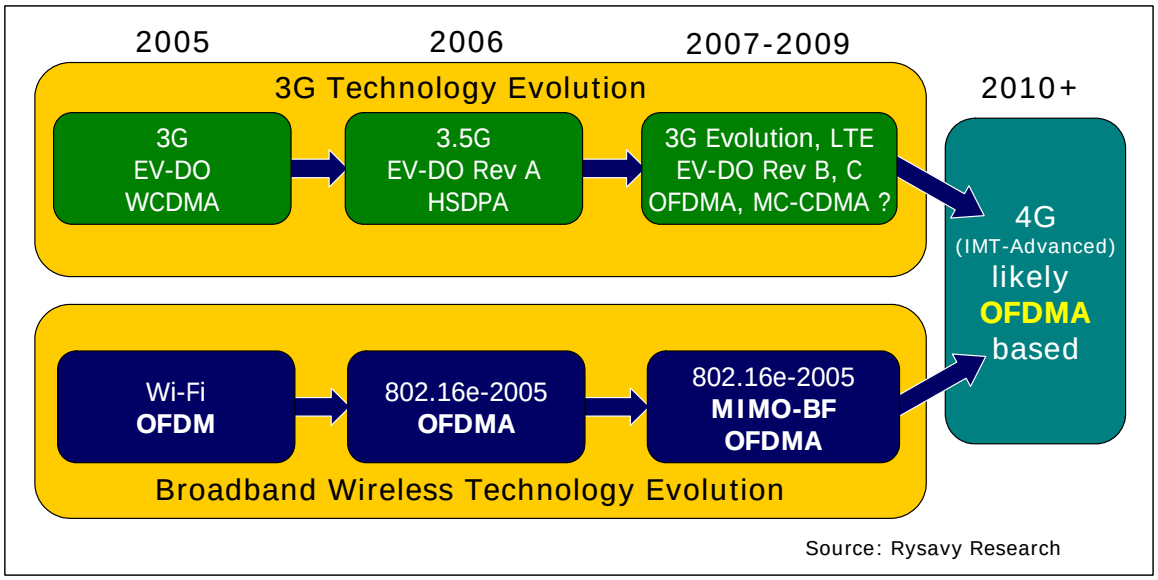

Figure 3: Mobile Technologies are Converging

6.0 The IEEE and the WiMAX Forum

Both the WiMAX Forum and the IEEE are members of ITU-T and ITU-R in the category of "Regional and Other International Organizations". In addition the WiMAX Forum is also an ITU-D Member. It is in this capacity that both organizations are cooperating in presenting a complete and consistent submission to ITU-R WP8F for inclusion of IP-OFDMA within the IMT family of radio transmission technologies as part of Rec. ITU-R M.1457-7.

The WiMAX Forum is an industry-led non-profit organization with worldwide representation and more than 400 members including service providers, equipment vendors, component, and content suppliers. Its primary mission is to ensure equipment compliance and interoperability through a certification process it develops and administers. The WiMAX Forum is also collaborating with the HiperMAN group within the ETSI BRAN Technical Committee. This multiparty collaboration has resulted in full harmonization between ETSI HiperMAN and IEEE 802.16. With its diversity of membership and worldwide participation, the WiMAX Forum is well positioned to meet its goal of achieving worldwide adoption and harmonization of a standards-based broadband wireless solution based on the IEEE 802.16 air interface standard with assured interoperability. This will lead to economies of scale and lower prices for WiMAX equipment.

The WiMAX Forum is organized into several working groups to facilitate its efforts. Driven by market requirements developed by the WiMAX Forum's Service Provider Working Group, the Technical Working Group develops the WiMAX system profiles that specify the features of the IEEE standard that are necessary to implement in a product to gain WiMAX Forum certification. The mobile WiMAX system profiles enable mobile systems to be configured based on a common base feature set, thus ensuring baseline functionality for fully interoperable terminals and base stations.

The WiMAX Forum's Regulatory Working Group is actively engaged with regulatory agencies to promote worldwide spectrum harmonization and a flexible regulatory framework. This effort helps to minimize the number of profiles required for worldwide applicability of WiMAX systems resulting in greater manufacturing efficiencies and lower equipment costs.

The WiMAX Forum Network Working Group is focused on the higher-level networking specifications [Ref. 6] above the radio interface specifications in the IEEE 802.16 air interface standard. The combined specifications of IEEE 802.16 and the WiMAX Forum help define the complete end-to-end system solution for a mobile WiMAX network. This process, which resulted in the mobile WiMAX Release-1 profiles, is illustrated in Figure 4.

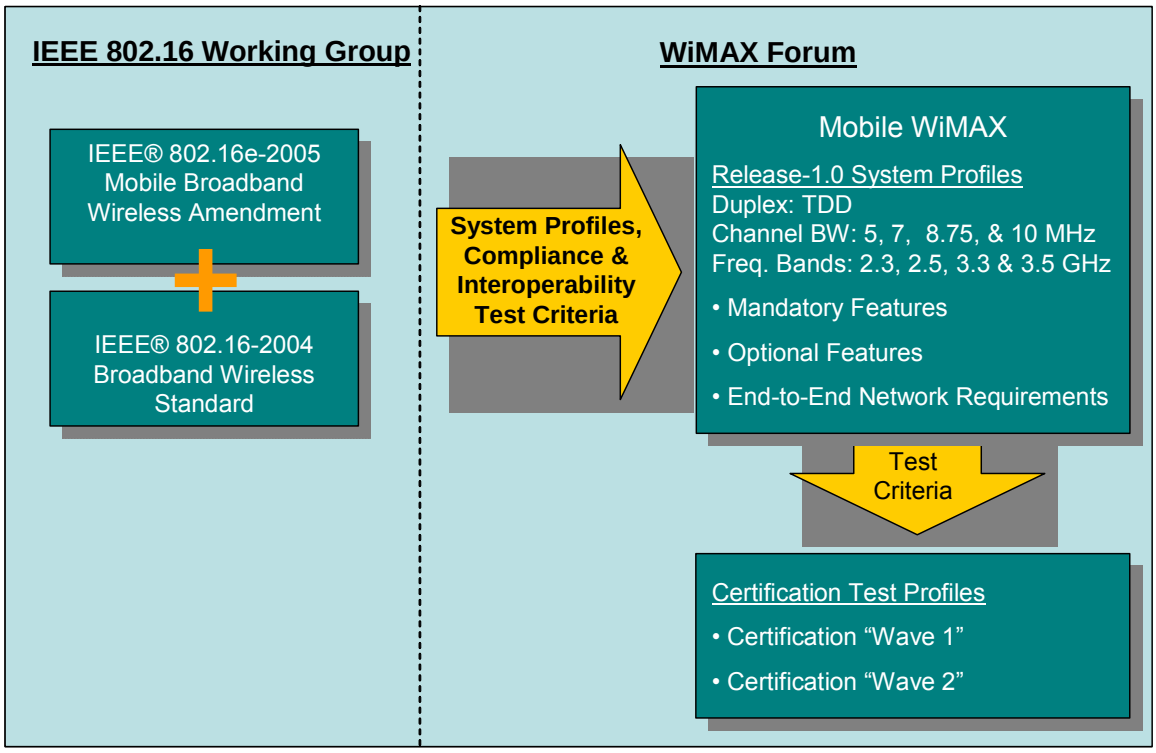

Figure 4: Role of IEEE and WiMAX Forum with 802.16e-2005

7.0 Conclusion

WiMAX technology has quickly gained worldwide acceptance. Mobile WiMAX products with OFDMA and support for full mobility will be available beginning in 2007, and several major operators have already announced plans for deployment. The inclusion of the mobile WiMAX technology, designated as IP-OFDMA, in the IMT-2000 family of radio interfaces will provide operators another viable alternative for upgrading the capacity and performance of their existing mobile networks to enable the delivery of new value-added services. With the OFDMA access technology added to FDMA, TDMA, and CDMA within IMT-2000, operators will have greater opportunity to match their technology choice to their business model to help assure a winning business case.

In the longer term, further IEEE 802.16 attributes, such as those driven by the future IEEE 802.16m project, will lay the groundwork for further OFDMA-based technology enhancements. The WiMAX Forum and the IEEE 802.16 Working Group share the view that this on-going effort, in cooperation with ITU-R WP8F, will result in a converged solution for future broadband wireless networks and fulfill the vision of IMT-Advanced.

Acronyms

3GPP	3G Partnership Project
3GPP2	3G Partnership Project 2
AAS	Advanced Antenna System
BF	Beam Forming
BRAN	Broadband Radio Access Network
CCI	Co-Channel Interference
CDMA	Code Division Multiple Access
DECT	Digital Enhanced Cordless Communication
DL	Downlink
DVB	Digital Video Broadcast
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved-UMTS Terrestrial Radio Access
EV-DO	Evolution-Data Optimized
EV-DV	Evolution-Data Voice
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FFT	Fast Fourier Transform
H-ARQ	Hybrid Automatic Repeat Request
HHO	Hard Hand Off
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IMS	IP Multi-Media Subsystem
IP	Internet Protocol

ITU	International Telecommunications Union
LOS	Line-of-Sight
LTE	Long Term Evolution
MAN	Metropolitan Area Network
MBS	Multicast and Broadcast Service
MC-CDMA	Multi-Carrier Code Division Multiple Access
MIMO	Multiple Input Multiple Output
MMD	Multi-Media Domain
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
QoS	Quality of Service
RTT	Radio Transmission Technology
SAE	System Architecture Evolution
SIMO	Single Input Multiple Output
SISO	Single Input Single Output
SM	Spatial Multiplexing
STC	Space Time Coding
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
UWC	Universal Wireless Communication
WiBro	Wireless Broadband
W-CDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access

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