WiMAX and the IEEE 802.16m Air Interface Standard - April 2010

Introduction

The IEEE 802.16e-2005 amendment to the IEEE Std 802.16-2004 Air Interface Standard which added Scalable-Orthogonal Frequency Division Multiple Access (S-OFDMA) and many other features for support of mobility has provided the basis for WiMAX System Release 1. Further specification enhancements for Release 1 were provided with IEEE Std 802.16e-2009. The first WiMAX System Release 1 deployments took place in 2006. Estimates by the WiMAX Forum indicate that as of the end of 2009, WiMAX service providers have covered more than 600 million people with over 500 deployments in over 140 telecommunications markets worldwide[1].

In December 2006 the IEEE launched an effort to further evolve the IEEE 802.16 WirelessMAN-OFDMA specification. This amendment, known as 802.16m, is designed to meet or exceed the requirements of IMT-Advanced (the 4th generation

IMT-Advanced: *International Mobile Telecommunications - Advanced (IMT-Advanced) is a term used by the ITU to describe mobile communication systems which go further than that of IMT-2000. Previously, IMT-Advanced was known as "systems beyond IMT-2000" and is often referred to as 4G. In establishing the requirements for IMT-Advanced, the ITU has attempted to anticipate the wide range of application and service demands required for future mobile networks that would need to be widely deployed in many countries in the 2012-2015 timeframe. In addition to being the driving force for IEEE 802.16m, IMT-Advanced is also the basis for LTE, and LTE-Advanced. IEEE 802.16e is already included in IMT-2000 while IEEE 802.16m and LTE-Advanced are the only two technologies submitted for IMT-Advanced. Both are expected to be included.*

1 These numbers also include pre-2006 WiMAX deployments based on OFDM-based IEEE 802.16-2004.

of cellular systems). With a number of stringent requirements for backwards compatibility, the 802.16m amendment will provide the basis for WiMAX System Release 2 and provide existing WiMAX operators a graceful migration path to gain performance enhancements and add new services. The IEEE 802.16m task group has more than 300 participating individuals from approximately 100 organizations from two dozen countries. As was the case for 802.16e-2005, 802.16m is designed to support frequencies in all licensed IMT bands below 6 GHz and include TDD and FDD duplexing schemes as well as half-duplex FDD (H-FDD) terminal operation to ensure applicability to the wide range of worldwide spectrum assignments.

Completion of the IEEE 802.16m specification is expected in the 3rd quarter of 2010 with ratification soon thereafter. Initial availability of WiMAX System Release 2 products based on 802.16m is anticipated in the 2012 timeframe.

This paper provides an overview of the enhancements incorporated in the IEEE 802.16m amendment and subsequently, WiMAX System Release 2. For the purposes of discussion the planned performance enhancements can be grouped into the following six categories:

- Increased Coverage and Spectral Efficiency
- Increased Capacity for Data and VoIP
- Lower Latency and QoS Enhancements
- Interworking with other Wireless Networks
- Power Conservation
- Other Advanced Features and Supported Services

Each of these categories will be covered in greater detail in the following sections.

Coverage and Spectral Efficiency

The IEEE 802.16m amendment provides an improvement in the link budget over WiMAX System Release 1 of at least 3 dB with the same antenna configuration. This will provide a 20-30% increase in cell coverage area in a typical non line-of-sight environment. Alternatively the improved link budget can be translated to increased cell edge user throughput resulting in a two times improvement over WiMAX System Release 1. Additional coverage benefits with 802.16m will be realized with support for more advanced antenna systems and with enhanced support for *integrated multi-hop relay and femto-cells*. The latter capabilities provide a cost-effective means to extend cell coverage and fill gaps in coverage caused by obstructions and shadowing.

Several other enhancements included in IEEE 802.16m will improve spectral efficiency for data services. These enhancements include:

- Extended and improved MIMO modes with emphasis on multi-user

MIMO (MU-MIMO) on both DL and UL to enable support for up to 8 data streams in the DL and up to 4 data streams in the UL.

- Improved open-loop power and closed-loop control
- Advanced interference mitigation techniques including fractional frequency reuse and inter-base station coordination
- More efficient use of pilot tones with new sub-channelization schemes and a cyclic prefix of 1/16 vs. 1/8 to reduce layer 1 overhead in both DL and UL
- Enhanced control channel design on both DL and UL with;
    - Reduced overhead
    - Improved coverage through power boosting and optimized channel coding
    - HARQ protection for control messages

The net result of these enhancements will provide more than 2 times improvement in average channel spectral efficiency. The peak and average spectral efficiency performance for IEEE 802.16m is summarized in the following table[2] for a low user mobility scenario.

Parameter	Antenna Configuration	Performance
Peak DL Spectral Efficiency	(2x2) MIMO (4x4) MIMO	8.5 bps/Hz 17.0 bps/Hz
Average DL Spectral Efficiency	(4x2) MIMO	3.2 bps/Hz 0.32 bps/Hz/User
DL Cell-Edge User Throughput	(4x2) MIMO	0.09 bps/Hz
Peak UL Spectral Efficiency	(1x2) SIMO (2x4) MIMO	4.6 bps/Hz 9.3 bps/Hz
Average UL Spectral Efficiency	(2x4) MIMO	2.6 bps/Hz 0.26 bps/Hz/User
UL Cell-Edge User Throughput	(2x4) MIMO	0.11 bps/Hz/User

Table 1: Spectral Efficiency Performance for IEEE 802.16m

Increased Capacity for Data and VoIP

Data Capacity: The spectral efficiency enhancements described in the previous section lead directly to increased channel data capacity and increased peak data rates. The following charts provide a summary for the peak DL channel and peak UL channel data rates with a comparison of WiMAX System Release 2, based on IEEE 802.16m, and WiMAX System

2 For average DL and UL spectral efficiency the assumptions are: Frequency reuse =1, 10 users per sector or channel, full-buffer data traffic, and Urban Microcell test environment as specified in IMT-Advanced.

Release 1, based on IEEE 802.16e-2005 and 802.16e-2009.

In Figure 2, for cases where the mobile station is configured with a (1x2) SIMO antenna configuration, UL collaborative MIMO (CM) is assumed. This enables the output from each of two users with a single transmit antenna to be combined over the same time and frequency resource block to double the UL channel data rate.

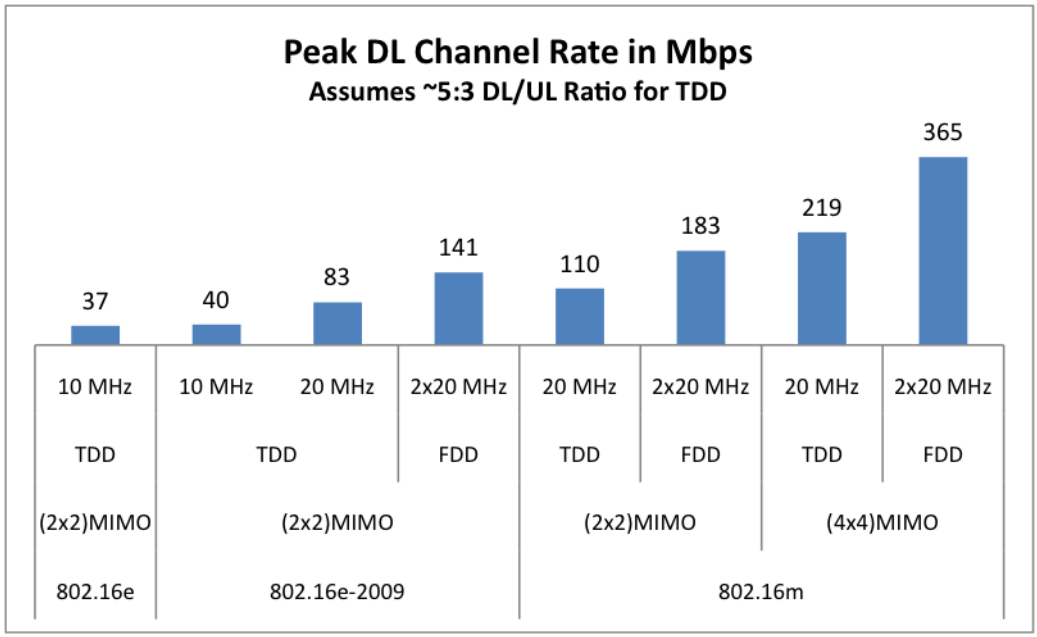

Figure 1: Peak DL Channel Data Rate Summary

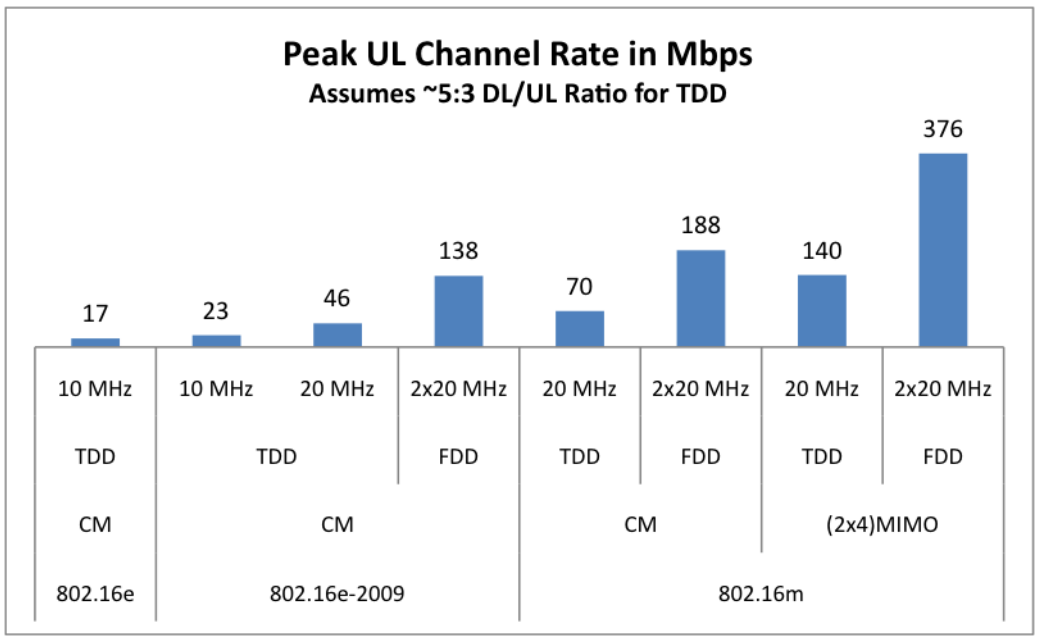

Figure 2: Peak UL Channel Data Rate Summary

Multi-Carrier Support: The IEEE 802.16m amendment also supports channel aggregation of contiguous or non-contiguous channels to provide an effective bandwidth up to 100 MHz. The channels do not need to have the same bandwidth nor do they need to be in the same frequency band. This capability will enable operators with access to multiple channels or licenses to achieve significantly higher peak and average data rates than is achievable with individual channels. Aggregating several 20 MHz channels, for example, could support peak data rates exceeding 1 Gigabit/sec.

VoIP Capacity: With persistent and group scheduling, faster HARQ retransmissions, rate matching, optimized QoS support, and the other spectral efficiency enhancements described in the previous section, VoIP capacity is significantly increased with 802.16m. The following chart summarizes the improvements for VoIP capacity assuming AMR 12.2 kbps speech codec[3] and the Urban Microcell test environment as specified by IMT-Advanced with user mobility of 3 km per hour. With (4x2) MIMO in the DL and (2x4) MIMO in the UL, WiMAX System Release 2 will be able to support 1600 bidirectional VoIP sessions per sector or 4800 sessions per 3-sector cell with an FDD system and a 2x20 MHz channel pair.

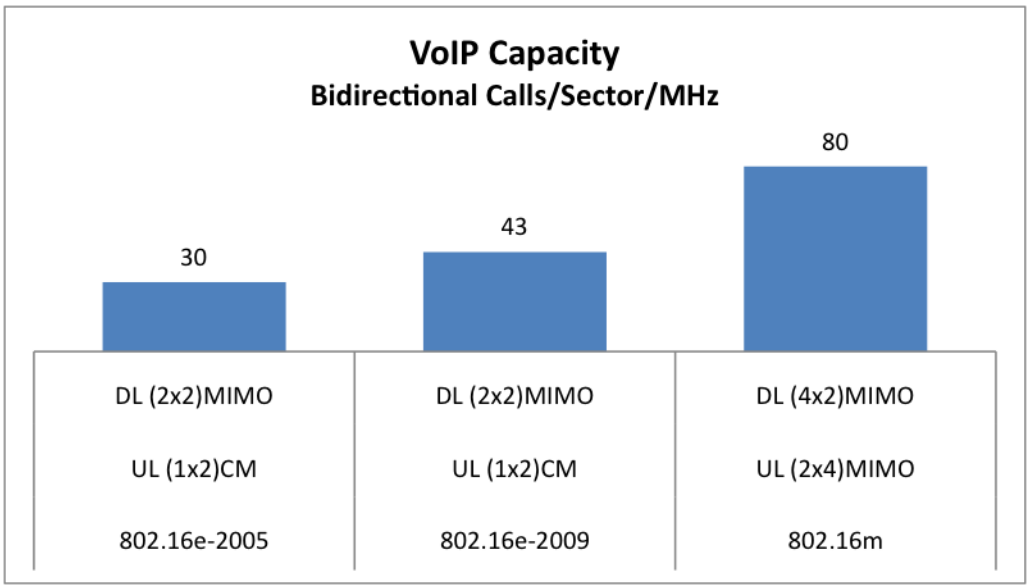

Figure 3: VoIP Capacity

Lower Latency and QoS Enhancements

Latency improvements with IEEE 802.16m are achieved with the use of a new sub-frame based[4] frame structure rather than a fixed 5 ms frame as used with WiMAX System Release 1. This enables faster air-link transmissions and retransmissions resulting in shorter user plane and

3 VoIP capacity would be ~50% higher with the AMR 7.95 kbps speech codec
4 Frame structure for 802.16m: 20 ms Super Frame, 5 ms Frame, 0.617 ms Sub-Frame

control plane latencies. The key goal for 802.16m is to minimize latency for all aspects of the system including air link delay, state transition delay, access delay, and handover interruption time to guarantee QoS for all services called for in IMT-Advanced.
Specific latency objectives for IEEE 802.16m are:

- Link Layer/User Plane: < 10 ms DL or UL
- Hand-Off Interruption: < 30 ms
- Control Plane, Idle to Active: < 100 ms

This represents a significant improvement over 802.16e-2005 latency and greatly enhances the QoS for latency-sensitive real-time applications such as VoIP, on-line business and financial transactions, real-time gaming, navigational applications, etc.
IEEE 802.16m will be able to support multiple QoS parameter sets for a single service flow. This will provide the flexibility to meet the individual QoS parameters established for individual multimedia classes established by IMT-Advanced. These classes are defined as follows:

- Low Multimedia: Data speed up to 144 kbps
- Medium Multimedia: Data speed up 2 Mbps
- High Multimedia: Data speed up to 30 mbps
- Super High Multimedia: Data speed up to 100 Mbps or possibly 1 Gbps

In addition, some of the 802.16m features already cited will enhance the end-user experience. For example:

- Higher peak and average channel data rates result in an enhanced user experience throughout the cell coverage area.
- The use of femto-cells can lead to higher average user throughput for users at the cell edge or in areas adversely impacted by obstructions.

Interworking with Other Wireless Networks

To facilitate global roaming and internetwork connectivity, WiMAX System Release 2 based on 802.16m ensures backwards compatibility with WiMAX System Release 1 based on 802.16e-2009 and improves coexistence and enhances interworking with other Radio Access Technologies (RAT). Concurrent operation of IEEE 802.16m and non-802.16m technologies on the same mobile station are also supported.

Specifically, to ensure seamless connectivity to alternative wireless networks, 802.16m provides a shorter handoff interruption time. Other Radio Access Technologies include:

- WiFi Networks

- 3GPP: HSPA, LTE, and LTE Advanced
- 3GPP2: 1x-EVDO

Power Conservation

To improve battery life in mobile stations, IEEE 802.16m provides enhancements in ***Sleep Mode*** and ***Idle Mode*** operation for the reduction in power consumption in 802.16m-based mobile stations. To improve Sleep Mode efficiency, 802.16m provides a mechanism for dynamically adjusting the duration of sleep windows and listening windows based on traffic conditions. Idle Mode efficiency is improved by enabling the mobile station to become available periodically for broadcast traffic without the need to register with a specific 802.16m base station.

IEEE 802.16m/WiMAX System Release 2 backwards compatibility ensures:

- *A WiMAX System Release 2 Mobile Station will interoperate with a WiMAX System Release 1 Base Station*
- *A WiMAX System Release 2 Base Station and a WiMAX System Release 1 Base Station can coexist on the same RF carrier*
- *A WiMAX System 2 Base Station will support both WiMAX System Release 1 and WiMAX System Release 2 Mobile Stations*
- *A WiMAX System Release 2 Base Station will support handoff of a WiMAX System Release 1 Mobile Station to or from a WiMAX System Release 1 Base Station or a WiMAX System Release 2 Base Station*
- *A WiMAX System Release 2 Base Station will efficiently interoperate with a WiMAX System Release 1 Mobile Station*

Other Advanced Features and Supported Services

Other key enhancements and features planned for the IEEE 802.16m amendment and WiMAX System Release 2 includes:

- Enhanced Multicast Broadcast Services (E-MBS) to provide greater broadcast and multicast spectral efficiency and support for switching between broadcast and unicast services whether on the same or on different frequencies.
- Enhanced GPS-based and Non-GPS-based Location Based Services (LBS) using triangulation schemes with < 30 seconds latency for location determination.
- Self-Organizing Network (SON) features to enable self-configuration and self-optimization. Self-configuration enables true plug and play of network nodes and cells as well as fast reconfiguration and compensation in cases of failure. Self-optimization ensures optimal network performance with respect to service availability, QoS, network efficiency, and throughput under changing traffic and environmental conditions.
- Enhanced security with more advanced encryption schemes assuring confidentiality of user identity and user-generated data packets (e.g. location privacy and user identity protection).
- Mobility: An IEEE 802.16m mobile station will maintain a connection

up to 350 km/hr and in some cases 500 km/hr depending on the operating frequency band.

Conclusion

The IEEE 802.16m amendment to the IEEE 802.16 WirelessMAN-OFDMA specification is on track for completion in Q3-2010 with ratification in Q4-2010. This amendment will be the basis for WiMAX System Release 2. This is one of only two technologies being considered by the ITU-R for IMT-Advanced. 3GPP LTE-Advanced, which is currently a work item in the 3GPP standards body, is the other technology under consideration. Currently 45 companies have actively supported the candidacy of IEEE 802.16m as an IMT-Advanced technology and expectations are that both LTE-Advanced and 802.16m will be included.

The performance enhancements defined in IEEE 802.16m build on the capabilities established with IEEE 802.16e-2005, an OFDMA-based technology with 4 years of worldwide, field-proven experience. With assured backwards compatibility, WiMAX System Release 2 will provide a graceful migration path for today's WiMAX operators to further enhance current network performance and new operators can deploy WiMAX with the confidence that they have selected a proven technology that is structured to meet current and future network demands. With this evolutionary growth path, the WiMAX technology is well-positioned to meet the challenges and demands anticipated for the next generation of mobile networks.