Mobile WiMAX: A Performance and Comparative Summary

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Introduction

Another key WiMAX milestone has been reached with the approval of the Mobile WiMAX systems profiles in February 2006. Mobile WiMAX based on the 802.16e-2005 enables WiMAX systems to address portable and mobile applications in addition to fixed and nomadic applications. This paper provides a brief overview of mobile WiMAX and presents performance data based on simulations as to how mobile WiMAX compares with HSPA and EVDO, capacity enhancements specified by 3GPP and 3GPP2 for WCDMA and CDMA2000 mobile networks respectively. For a more in-depth discussion of these topics the reader is referred to white papers available on the WiMAX Forum Website [1,2].

Mobile WiMAX

Mobile WiMAX introduces OFDMA and supports several key features necessary for delivering mobile broadband services at vehicular speeds greater than 120 km/hr[1] with QoS comparable to broadband wireline access alternatives. These features and attributes include:

- Tolerance to Multipath and Self-Interference with subchannel orthogonality in both the DL and the UL.
- Scalable Channel Bandwidths from 1.25 to 20 MHz
- Time Division Duplex[2] (TDD) is defined for the initial mobile WiMAX profiles for its added efficiency in support of asymmetric traffic and channel reciprocity for easy support of advanced antenna systems.

[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] FDD will be considered in future profiles to address specific market opportunities or local spectrum regulations

- Hybrid-Automatic Repeat Request (H-ARQ) provides added robustness with rapidly changing path conditions in high mobility situations.
- Frequency Selective Scheduling and subchannelization with multiple permutation options, gives mobile WiMAX the ability to optimize connection quality based on relative signal strengths to specific users.
- Power Conservation Management ensures 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, MediaFLO 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
- Smart Antenna support aided by subchannelization and channel reciprocity enables a wide range of advanced antenna systems including beamforming, space-time coding and spatial multiplexing.
- Fractional Frequency Reuse controls co-channel interference to support universal frequency reuse with minimal degradation in spectral efficiency.
- 5 millisecond Frame Size provides optimal tradeoff between overhead and latency.

Release-1 Mobile WiMAX Profiles

The frequency bands and channel bandwidths selected by the WiMAX Forum for the initial system profiles cover many of the worldwide spectrum allocations suitable for mobile WiMAX. The following table summarizes these profiles. Other frequency bands, channel bandwidths and FDD will be considered for future profiles based on specific market opportunities.

Channel BW	FFT Size	Other bands TBD	2.3-2.4 GHz	2.305-2.32, 2.345-2.36 GHz	2.496-2.69 GHz	3.3-3.4 GHz	3.4-3.8 GHz
1.25 MHz	128						
5.0 MHz	512		TDD	TDD	TDD	TDD	TDD
7.0 MHz	1024					TDD	TDD
8.75 MHz	1024		TDD				
10 MHz	1024		TDD	TDD	TDD	TDD	TDD
20 MHz	2048						

Table 1: Release-1 System Profiles for Mobile WiMAX

Mobile WiMAX Timeline

WiMAX-certified products based on 802.16-2004 for fixed and nomadic applications are now commercially available and many of the existing fixed WiMAX trials will evolve into full commercial deployments in the coming months. A second WiMAX certification lab was announced in February and is expected to be fully operational in Q3-2006. The WiMAX Forum is working to a planned schedule for certification of Mobile WiMAX-based products starting in Q4-2006.

The first commercial portable/mobile application for WiMAX certified products is expected to take place in Korea with the launch of WiBro services [3]. Products for WiBro services operate in the licensed 2.3 GHz frequency band with an 8.75 MHz channel bandwidth. This initial product launch will use SISO antenna configurations and support mobile speeds >60 km/hr. Additional deployments of Mobile WiMAX products are expected in the early 2007 time frame.

	2004	2005	2006	2007
802.16-2004 Air Interface Standard Ratified	▲			
802.16/HiperMAN Harmonization		▲		

	2004	2005	2006	2007
1st Certification Lab Opens (Cetacom, Spain)		▲		
1st Certified Fixed WiMAX Products			▲	
802-16e Air Interface Standard Ratified		▲		
Mobile WiMAX Rel-1 System Profiles			▲	
Mobile WiMAX Rel-1 Certification Profiles			▲	
2nd Certification Lab Opens (TTA Labs, Korea)			▲	
Launch of WiBro services in Korea			▲	
1st Mobile WiMAX-Certified Products				▲

Table 2: WiMAX Timeline

Mobile WiMAX and 3G

Enhancements for CDMA-based 3G systems, EVDO and HSDPA/HSUPA (HSPA), offer 3G operators the opportunity to upgrade the throughput performance of CDMA2000 and WCDMA networks respectively. EVDO-Rev A and HSDPA are available and being deployed extensively. EVDO-Rev B and HSUPA will be available in the 2007 to 2008 time frame. The expected availability of mobile WiMAX in 2007 will provide existing and new mobile operators an added alternative to consider for the delivery of broadband mobile services.

Performance Comparison

Using a commonly accepted 1xEV-DV evaluation methodology [4,5,6] for 3G systems, mobile WiMAX can be compared to the 3G enhancements. Table 4 summarizes the multipath models used for the simulation. The simulation parameters for the comparison are similar except for the following:

- EVDO and HSPA are FDD implementations operating on a carrier frequency of 2.0 GHz whereas mobile WiMAX is TDD operating at 2.5 GHz.
- EVDO and HSPA assume a single Tx antenna and dual Rx antennas (1x2 SIMO) with RAKE receivers in both DL and UL. For Mobile WiMAX, 1x2 SIMO is assumed for one case and for a second case, 2x2 MIMO with Space Time Coding and Vertical Spatial Multiplexing with Adaptive MIMO Switching are assumed in

the DL and two-user collaborative spatial multiplexing assumed in the UL. Maximum Likelihood Symbol Detection is assumed at the receivers in both DL and UL. Whereas the latter configuration represents the baseline functionality as specified in the Release-1 system profile for Mobile WiMAX, many early WiMAX deployments will be configured in 1x2 SIMO mode.

Channel Model	# of Paths	Speed	Fading	# of Users per Sector
Model A	1	3 km/hr	Jakes	3 (30%)
Model B	3	10 km/hr	Jakes	3 (30%)
Model C	2	30 km/hr	Jakes	2 (20%)
Model D	1	120 km/hr	Jakes	1 (10%)
Model E	1	0, $f_{Doppler}$ = 1.5 Hz	Rician Factor K = 10 dB	1 (10%)
			Total Users per Sector	**10**
			Total Users per Cell	**30**

Table 3: Multipath Channel Models for Performance Simulation

Figure 1 provides a throughput comparison and Figure 2 provides a spectral efficiency comparison of mobile WiMAX with EVDO and HSPA. EVDO-Rev A is deployed with a single 1.25 MHz carrier. For EVDO-Rev B, which supports multicarrier capability, a 3-carrier implementation is assumed to provide a more direct comparison to HSPA and mobile WiMAX with respect to the occupied spectrum.

The mobile WiMAX performance is presented for a DL/UL ratio of 1:1 and 3:1 to show the benefit of TDD with data-centric asymmetric traffic. This represents the range of DL to UL ratios supported by the mobile WiMAX Release-1 profile.

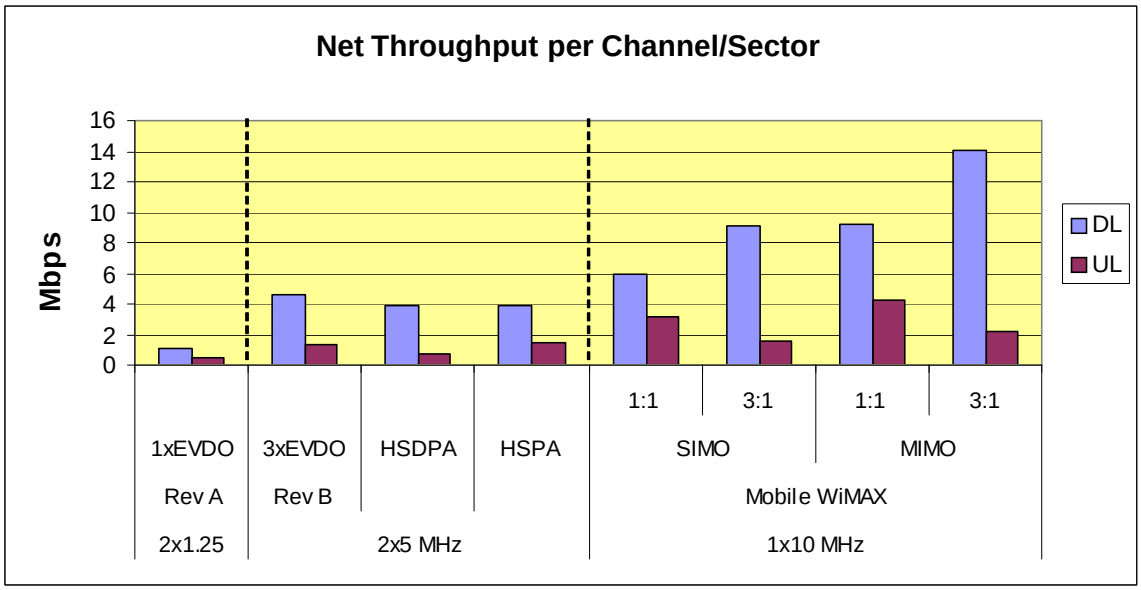

Figure 1: Sector Throughput Comparison

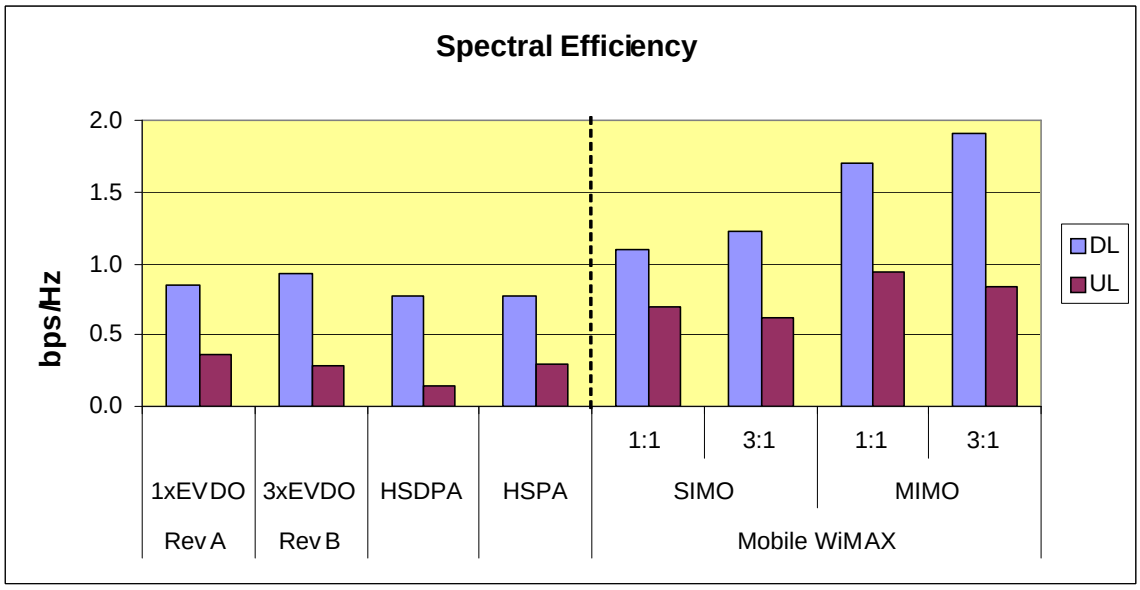

Figure 2: Spectral Efficiency Comparison

Business Case Impact

From a business case perspective the throughput and spectral efficiency advantages of mobile WiMAX results in fewer base stations to achieve a desired data density. The example in Figure 3 summarizes the number of base stations required to achieve a DL data density of 215 kilobytes per sec per sq-km over a 129 sq-km coverage area. Fewer base stations greatly reduces the network capital costs for a given network capacity and, with lower equipment maintenance costs, results in lower operating expenses as well.

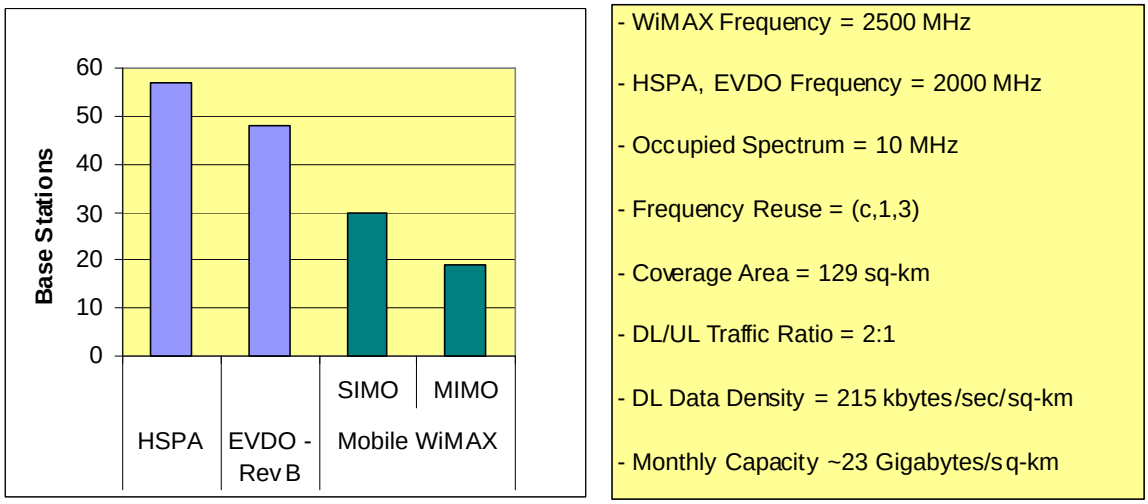

Figure 3: Number of Required Base Stations

The economic and performance benefits of mobile WiMAX will have great appeal to new Greenfield operators as well as existing mobile and wireline operators. Existing 2G and 3G operators can consider mobile WiMAX overlays to existing mobile networks to add capacity for the delivery of new value-added services. DSL and cable operators can use mobile WiMAX to cost-effectively extend the reach of existing wireline networks to address new customers.

Conclusion

The WiMAX technology continues to evolve with the WiMAX Forum's approval of the Release-1 mobile WiMAX system performance profiles based on the 802.16e-2005 amendment. With OFDMA, mobile WiMAX can meet the stringent requirements necessary for the delivery of broadband services in a challenging mobile environment. Performance simulations show that mobile WiMAX provides superior throughput and

spectral efficiency compared to planned 3G CDMA-based enhancements, EVDO and HSPA. These advantages will provide operators with added network capacity for the support of value-added services with fewer base stations than alternative approaches thus resulting in lower network capital and operating costs.

References

[1] WiMAX Forum website, “Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation”, 2006.

[2] WiMAX Forum website, “Mobile WiMAX – Part II: A Comparative Analysis”, 2006.

[3] “KT Corporation to Launch Commercial WiBro Services in Mid-2006” Press Release, Nov. 14, 2005.

[4] 3GPP TSG-RAN-1, "Effective SIR Computation for OFDM System-Level Simulations," R1-03-1370, Meeting #35, Lisbon, Portugal, November 2003.

[5] 3GPP TSG-RAN-1, System-Level evaluation of OFDM - further Considerations”, R1-031303, November 17-21, 2003.

[6] 3GPP2 C.R1002-0, CDMA2000 Evaluation Methodology, December 2004.