



Broadband Wireless Options: An Assessment

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Presentation Outline

- BWA Technology Choices & Advantages
- Technical Assessment of WiMAX
- Network Economics
- BWA Market Opportunity
- Conclusions



Advantages of 3G, Wi-Fi and WiMAX

The right wireless technology for the right application

3G Technologies

- 3G offers ubiquitous access to toll-quality voice & broadband data services within a wide area
 - Voice capacity and broadband data capabilities continue to grow
- 3G economies of scale are enormous, leading to greater product availability and lower costs
 - Advanced 3G technologies such as EV-DO Rev. A/B and HSDPA/HSUPA highly leverage existing 2G/3G network buildouts and coverage

Wi-Fi

- Wi-Fi offers a high-speed, low cost, wireless LAN connection for homes, campuses and enterprises
- 802.11n will enable 100+ Mbps throughputs
 - Market success is not predicated on service model

WiMAX

- WiMAX offers a cost effective backhaul alternative for 3G base stations and Wi-Fi hotspots
- WiMAX may supplement existing broadband services
 - Fixed broadband access in areas where it is not cost effective to deploy DSL, cable, fiber, landline, etc.
 - Market opportunity may be limited

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WiMAX Assessment





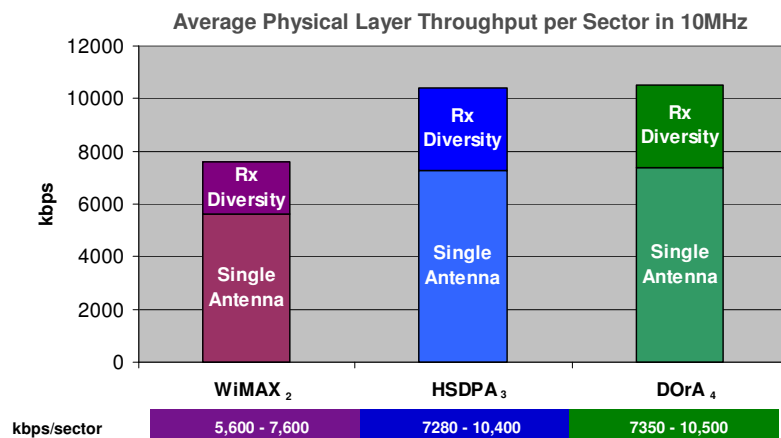
WiMAX Technology & Targeted Market Segments

- The WiMAX Forum promotes IEEE 802.16 standards to target two distinct market opportunities:
 - ❑ **802.16-2004: Fixed Broadband Wireless Access (FBWA)**
 - Wireless backhaul, LOS & NLOS
 - Competitive broadband offering to DSL, cable, etc.
 - OFDM technology (256 OFDM)
 - Uses a variety of bandwidths (3.5 MHz, 5.0/5.5 MHz, 7.0 MHz, and 10 MHz)
 - Targeted bands
 - Licensed: 2.5 GHz and 3.5 GHz
 - Unlicensed: 5.8 GHz
 - ❑ **802.16e: Portable & Mobile BWA**
 - Portable notebooks and mobile handsets, NLOS
 - OFDMA technology (128, 512, 1024 & 2048 FFT)
 - Uses a variety of bandwidths, initially 5 MHz, and claims 15 Mbps peak rates
 - Targeting bands extending to 6 GHz

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Downlink Throughput Comparison: DO and HSDPA Outperforms WiMAX in Mobile Environment



Simulation assumptions:

- 1 Full buffer; ITU channel models: pedA 3km/h 30%, pedB 10km/h 30%, vehA 30km/h 20%, pedA 120km/h 10%, Rician 10% for all technologies
- 2 No Guard band assumed for WiMAX, frequency reuse of 1 is considered
- 3 Perfect Linear MMSE equalizer assumed, back off 0.75dB
- 4 Equalizer gain simulated; 1.25MHz carriers, 7 in 10MHz

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Mobile WiMAX Performance

- **Extensive simulations based on proven ITU mixed channel model and 3G methodologies show:**
 - 3G Broadband offers greater spectral efficiency → higher data throughput
 - Mobile WiMAX spectral efficiency is in the order 0.5 to 0.8 bits/sec/Hz
 - DOrA & HSDPA spectral efficiency performance is **15%-35%** better than Mobile WiMAX in a FDD deployment scenario
- **Studies indicate that the spectral efficiency of Mobile WiMAX in TDD scenarios will be no different**
 - Physical Layer Design and basic technical framework between FDD and TDD scenarios are retained
 - Physical Layer Frame Structure is very similar
 - Control Channel design is very identical between FDD and TDD modes
 - Resource allocation, overhead management and interference reduction mechanisms are all similar between the two duplexing modes
- **IEEE802.20 technology is a far superior technology option for TDD unpaired spectrum with channel BWs scalable from 5 MHz up to 20 MHz**

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IEEE 802.20 Mobile Broadband Technology

- MIMO optimized
- FDD and TDD modes
- Radio channels up to 20 MHz wide in licensed spectrum
- User peak rates of over 260 Mbps (DL) and 60 Mbps (UL)
- Superior performance for all deployment scenarios
 - **Macro-cellular, micro-cellular and hotspots**
- System designed from ground up for mobile broadband
 - **Flexible airlink resource management with efficient, low-overhead signaling**
 - **Advanced interference management**
 - Distributed power control
 - Fractional frequency re-use for cell edge performance and
 - Frequency hopping modes
 - **Proven/mature mobility mechanisms provide seamless, low latency handoffs**
 - **Fast sector selection using uplink CDMA control channels**

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IEEE 802.20 Expected Throughput Performance

	FDD, BW per link		TDD 2:1, total BW	
	10 MHz	20 MHz	10 MHz	20 MHz
Peak Forward Data Rate (1)	140	290	91	190
Peak Reverse Data Rate	34	70	9	20
Forward Average Sector Throughput (2)	21	44	15	32
Reverse Average Sector Throughput (3)	12.5	26	3.4	7.1
Forward Spectral Efficiency (estimate) (2)	~2.2 bps/Hz		~2.3 bps/Hz	
Reverse Spectral Efficiency (estimate)(3)	~1.3 bps/Hz		~1.0 bps/Hz	

All data rates in Mbps, except where indicated

1 FL peak data rates based on 4x4 MIMO

2 FL throughput and Spec Efficiency is estimated based on 4x4 MIMO at vehicular speed 120 km/h, TDD DL/UL partitioning assumed to be 2:1.

3 RL throughput and Spec Efficiency is based on 4 Rx BS antennas at vehicular speed 120 km/h. TDD DL/UL partitioning assumed to be 2:1.

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Mobile WiMAX Link Budget

- Studies show WiMAX has a lower link budget than 3G technologies
 - DOrA & HSDPA offer ~**5dB** link budget advantage over Mobile WiMAX
 - Mobile WiMAX will require ~**2x** the number of cells to provide same coverage in same frequencies
 - Cell counts will be much higher, given the higher frequencies targeted by WiMAX

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General Observations

- **Inefficient message based power control (as opposed to bit based)**
 - Affects attainable link margins and data rates on the Uplink; Leads to lower Uplink average spectral efficiency
- **Inefficient message based sleep mode operation**
 - Leads to higher battery consumption
- **Inefficient handoff design**
 - Seamless soft handoffs will be difficult to implement
 - Network procedures are not properly defined
- **Limited number of simultaneous users can be supported**
 - High overhead

Mobile WiMAX is not optimally designed for mobility

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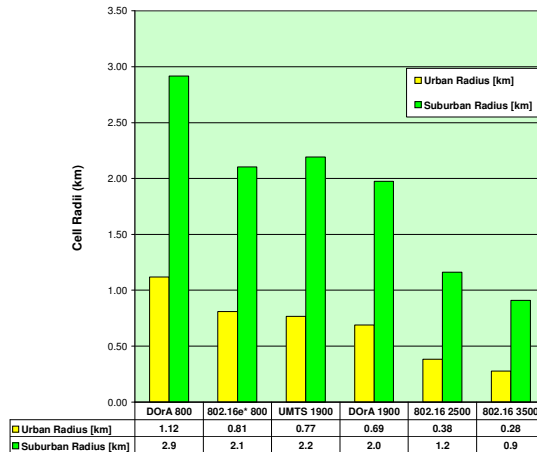


Network Economics



Cell Radius Comparison

- 3G technologies provide better coverage than WiMAX in the same frequency bands



Assumptions:

Link budget: DOrA and 802.16 RL minimum data rate at 9.6kbps, UMTS minimum data rate at 12.2kbps

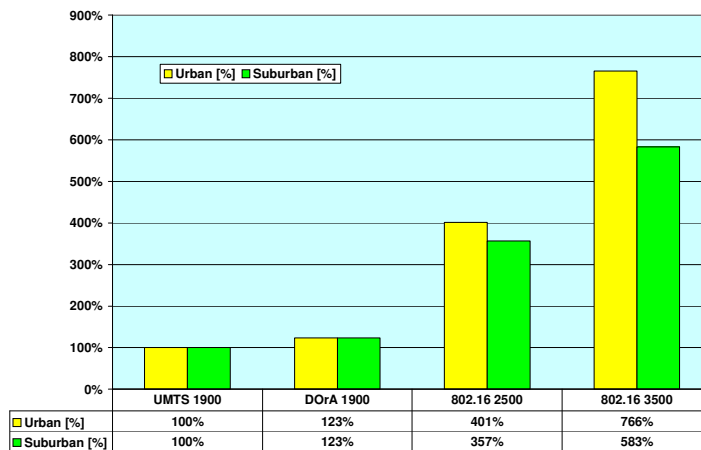
Propagation model: Hata model in 800MHz, Cost-Hata model in 1900MHz, 2500MHz and 3500MHz

* Comparison for 802.16e and CDMA2000 800 MHz frequency is not a typical implementation

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Normalized Site Counts Comparison

- 3G technologies need less sites than WiMAX to cover the same area



Assumptions:

Link budget: DOrA and 802.16 RL minimum data rate at 9.6kbps, UMTS minimum data rate at 12.2kbps

Propagation model: Cost-Hata model used for all the frequencies

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Network Economics: WiMAX, HSDPA & DOrA

• Spectral Efficiency: 3G Advantage

Spectral Efficiency	WiMAX 2 Rx	HSDPA 2 Rx	DOrA 2 Rx
In 10 MHz (bps/Hz/sector)	.76	1.04	1.05

Spectral Efficiency Assumptions:

- Sector throughput in 10MHz divided by 10MHz, unit: bps/Hz/Sector
- Simulation assumptions:
 - Full Buffer
 - ITU Channel Models/probabilities: *pedA 3km/h 30%, pedB 10km/h 30%, vehA 30km/h 20%, pedA 120km/h 10%, Rician 10%*
- WiMAX sector throughput: 2rx, 7600kbps in 10MHz. No guard band assumed, Frequency reuse 1
- DOrA sector throughput: 2rx with equalizer, 10,500kbps for 7 of 1.25MHz carriers in 10MHz

• Spectral efficiency drives network expenses

Network Expenses	WiMAX 2 Rx	HSDPA 2 Rx	DOrA 2 Rx
In 10 MHz (NetX/Gbyte)	\$12.00	\$10.40	\$10.37

NetX Assumptions:

- Network Expense includes all network operations expenses and depreciation on network capital
- 7.5% Busy Hour, Assumes 3 sector sites, Capacity Constrained Network
- Equipment Cost \$135k/3 Sector site
- Includes BHaul (\$4000/mbps/year) and Interconnect (\$3000/mbps/year) Expense



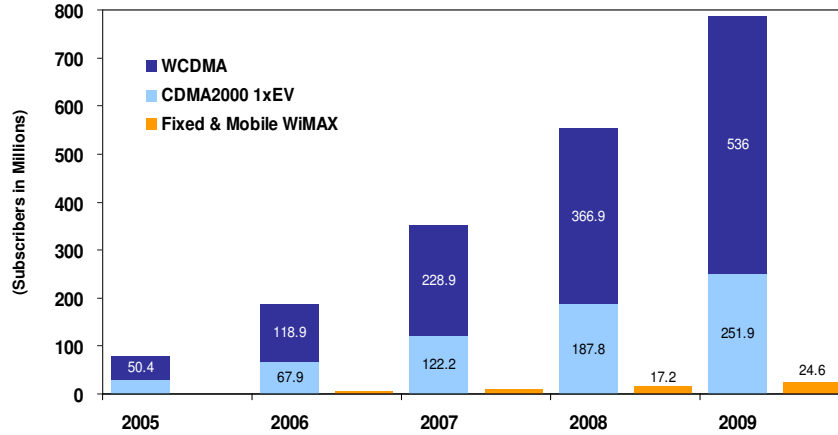
BWA Market Opportunity



Subscriber Forecasts by Technology

3G Broadband subscribers will approach 800 million within the Next 5 Years

Total Subscribers Worldwide (2005 - 2009)

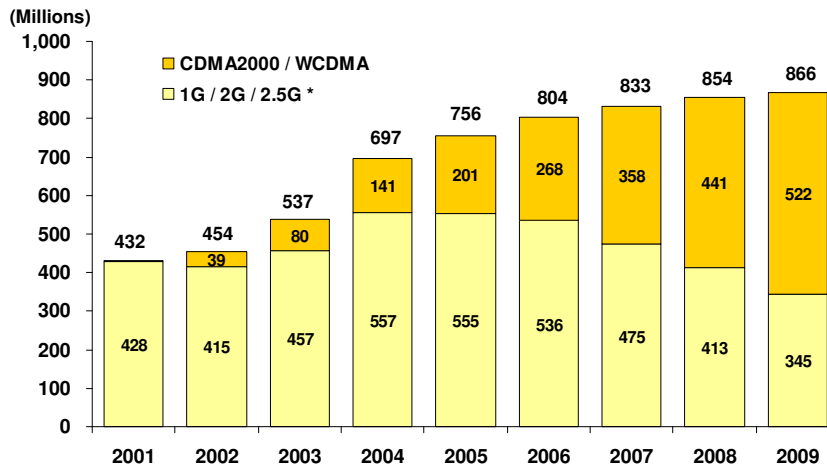


Sources:

1. WCDMA & CDMA2000 1xEV: Blended forecast from Strategy Analytics (Dec. 2004) and Yankee Group (March 2005); 1xEV includes 1xEV-DO & DV subs
2. WiMAX: Blended forecast from Strategy Analytics (Mar. 2005) and Gartner (Dec. 2004)

Global Wireless Device Shipments by Technology

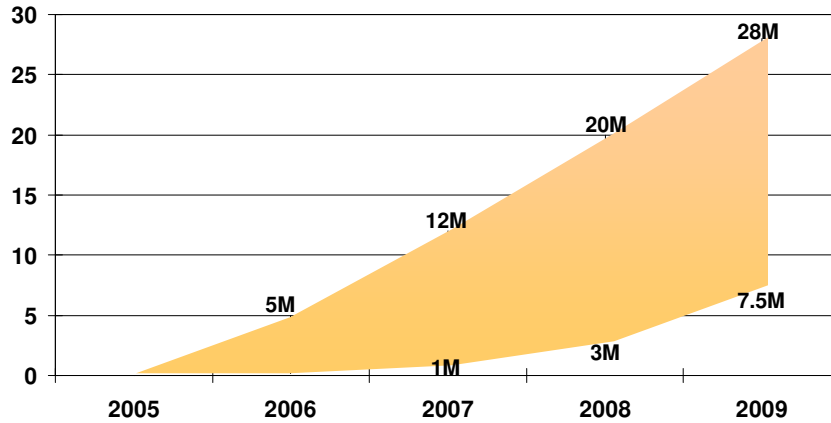
3G (CDMA2000 and WCDMA) will Make Up 60% of Total Shipments by 2009



* Includes cdmaOne, GSM/GPRS/EDGE, TDMA, PDC, and Analog

Source: Average of Strategy Analytics (August 2005) and Yankee Group (June 2005) handset forecasts

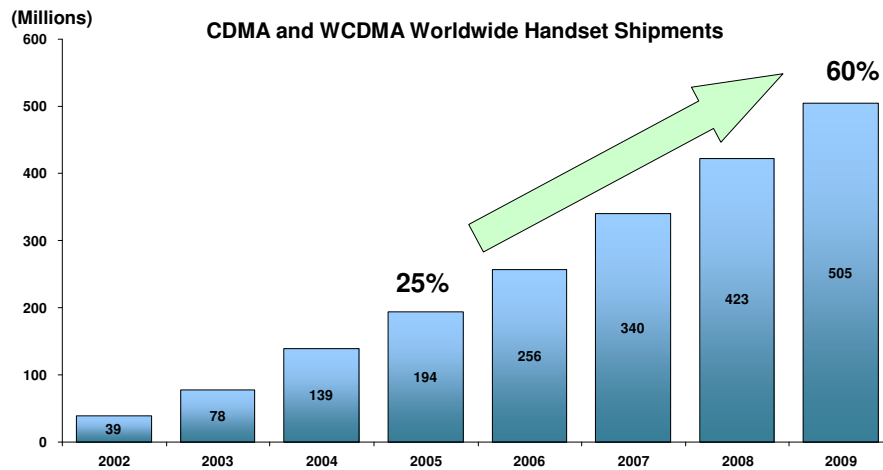
WiMAX* CPE / Subscriber Unit Forecasts



Shaded area represents ranges between lowest and highest forecasts for shipments of fixed and portable/mobile WiMAX CPEs/subscriber equipment. Forecasts include ABI Research (Q3, 2005), Forward Concepts (September 2005) and Strategy Analytics (March 2005).

*Includes both 802.16-2004 and 802.16e (fixed and portable/mobile) shipments

Industry Analysts Forecast 3G CDMA Devices Grow to 60% of Worldwide Sales by 2009



Source: Average of Strategy Analytics (August 2005) and Yankee Group (October 2005) handset forecasts

Wireless Market Opportunity

3G Broadband will create more industry value, with a focus on service revenue

2009 Market Size:

- 3G Evolution (incl. 3G mobile broadband)**

- \$394 B in service revenues¹
- \$114 B in equipment revenues²
- 960M subscribers by 2009³

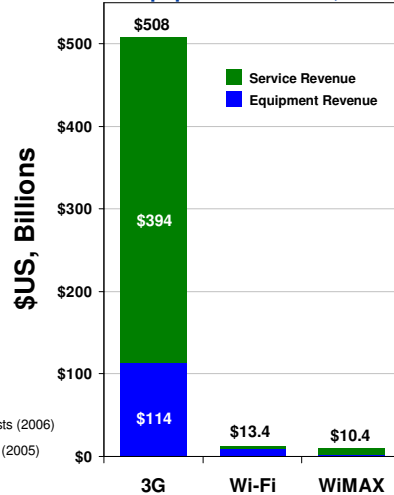
- Wi-Fi Evolution (802.11 a,b,g,n)**

- \$3.5 B in public Wi-Fi service revenues¹
- \$9.9 B in equipment revenues⁴
- 48M subscribers by 2009¹

- WiMAX (802.16-2004, 802.16e-2005)**

- \$7.4 B in service revenues¹
- \$3 B in equipment revenues⁵
- 25 M subscribers by 2009⁶

Worldwide Service and Equipment Revenue, 2009



¹ Source: Strategy Analytics (2006)
² Source: Average of Strategy Analytics and Yankee Group forecasts (2006)
³ Source: Average of IGR, Informa WCIS, Strategy Analytics and Yankee Group forecasts (2006)
⁴ Source: Forward Concepts (2005)
⁵ Source: Average of Strategy Analytics (2006), Gartner (2006) and Forward Concepts (2005)
⁶ Source: Average of Strategy Analytics (2006) and Gartner (2005)

Summary

Technical Performance

- 3G data rates and capacities are comparable to or better than Mobile WiMAX*
- 3G leverages existing 2G/2.5G coverage; 3G coverage is better than Wi-Fi & Mobile WiMAX
- 802.20 complements EV-DO evolution with a compelling TDD solution for large spectrum allocations

* Given equivalent channel bandwidths, coverage and allocated spectrum

Time to Market

- 3G broadband has at least a 4-year time-to-market advantage over Mobile WiMAX
- Since 2002, hundreds of 3G handsets, PDAs and PC card have been commercialized
- 3G technologies will be embedded into laptop PCs from leading manufacturers starting in 2005

Cost & Scale

- 3G devices can be purchased for \$50 in certain markets today*
- 3G forecasts indicate strong service revenues and equipment & device shipments**
- 3G expects to reach more than 800M subs, while WiMAX may reach 33M subs (2009)
- Multi-mode devices with 3G & MBWA 802.20 combine are poised to gain a major share of the Metro Area Deployments

Business Case

- 802.11a/b/g is available today at low price points
- 802.11n will offer better performance within the home and enterprise than WiMAX
- Unlike Wi-Fi, the WiMAX market opportunity will require an operator business case;
- 3G technologies will continue to lower the cost per bit for core operator services

* Commercial LG units shipping to Reliance in India
 ** Source: ABI, Gartner, IDC, In-Stat/MDR, Strategy Analytics, 2004 & 2005



Thank You

