

Wireless Broadband Assessment

September 2006









Agenda



- Wireless Broadband Evolution
- Assessing Wireless Broadband Options
 - Economics
 - Other Considerations
- Technology Roadmaps
 - PP Evolution
 - PP2 Evolution

Wireless Broadband Evolution





Network Evolution

- All-IP Network For Fixed-Mobile Convergence (VoIP & data)
- Co-existence of Different
 Access Networks for
 Various Needs
 - -Coverage, Mobility, Capacity, QoS, Data Rates ...

Mobile Device Evolution

- Convergence of Communication, Computing & CE Platforms
- Multi-mode Devices
 Connect to Various
 Access Networks
 - -Service Requirements, Availability, Cost ...

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Service Evolution

- User Behaviors Trend from Wired to Wireless in time
- Same Rich IP Apps and Services in all Environments
 - -Ubiquitous & Consistent Experience Desired 3

Network Evolution: Convergence Will Mean the Right Technology for the Right Service

Hybrid network based on different air interfaces with a common IP-based backbone

- Full range of devices access the same content across different IP networks
- Selection of access based on service requirements, availability, cost



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Device Evolution: Mobile Broadband is Key

Wireless Broadband, Mobility Increasingly Important to Device Vendors

- Initially, CPE gateways will be critical for VoIP, data
- Cost reductions expected with scale, market maturity
- Trickle down effect will introduce more capabilities in low end devices over time
- Economic development will lead to higher incomes
- Fixed CPEs will eventually give way to more portable devices

- Computers, Mobile Phones, CE
 Devices are Converging
- Most Devices Evolving Toward Mobility and Connectivity
 - Vendors embracing wireless for communication between devices.
 - Wireless capability important for market differentiation
- Growing File Sizes
 - Device sound, image, video quality are important differentiators.
 - Necessitate high transfer rates to be practical (USB 2.0, 802.11g, etc.)

Service Evolution: Markets Will Eventually Transition Toward Data and Mobility

Broadband Allows Service Mix to Evolve Gradually



Voice becomes a specialized data app

Assessing Wireless Broadband Options: Economic Considerations

• All Wireless Networks Entail the Same Kinds of Costs

- End-user devices
- Network operating expenses
 - E.g. maintenance, operations, backhaul, site rental
- Network capital depreciation
 - E.g. site acquisition, transceivers, RF engineering

Several Factors Have the Greatest Impact on Cost

- Scale
- Breadth and maturity of ecosystem
- Number of sites required (link budget)
- Capacity (spectral efficiency)



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Number of Subscribers Affects Scale, Ecosystem





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

Subscriber Numbers Correlate with **Equipment and Service Revenues**

WWAN Broadband will Create Industry Value, with a Focus on Service Revenue

2009 Market Size:

WWAN 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)

Device Volumes Impact Cost and Diversity



Global WWAN Device Shipment Forecasts



* Includes cdmaOne, GSM/GPRS/EDGE, TDMA, PDC, and Analog Source: Average of Strategy Analytics (August 2005) and Yankee Group (June 2005) handset forecasts

Device Volumes Impact Cost and Variety



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

Solid Ecosystems Require Strong Operator Support

E.g. 224 Commercial WWAN Operators in 95 Countries



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Broad and Mature Ecosystems Lead to Diversity of Devices

More than 180 CDMA2000 1xEV-DO Devices have been Commercialized by 30 Vendors



Samsung SCH-A990 3.2 Megapixel Camera, TV Out



Motorola Q Windows Mobile 5 Smartphone Edition



Samsung V740 14mm thin, 1.3MP Camera



Samsung SCH-i830 Windows Mobile 2003, WorldMode



HP Compaq nc6400 Embedded 1xEV-DO



Toshiba W41T 4GB Hard Disk Drive



LG KV3600 Enhanced 3D Gaming Graphics



LG VX8500 V-Cast - Streaming Video, 3DGames, MP3 Player, MicroSD QUALCOMM Proprietary



Casio W21CA 2.6 inch WQVGA, 2 MP Camera



Kyocera *Rx diversity*

Broad and Mature Ecosystems Lead to Diversity of Devices

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More than 200 WCDMA (incl. 22 HSPDA) Devices have been **Commercialized by 26 Vendors**





LG CU500 HSDPA, Bluetooth



Samsung P920 Video Conferencing, MP3, Bluetooth, USB



Sony-Ericsson W900i MP3 Player, Walkman



Fujitsu Lifebook Q2010 Embedded HSDPA



Motorola E1120 3 Megapixel. Barcode Scanner



Sanyo SA700iS 2.2" QVGA, miniSD GPS, Video Conferencing



LG U900 1.3 Megapixel, DVB-H, Video Conferencing



NEC N902iS 4 Megapixel, Camcorder, Barcode Scanner, GPS, MP3, removable miniSD



Sharp 703SH Macromedia Flash, **Bilingual menus**



ONDA N501HS WCDMA / HSDPA

The Number of Sites Multiplies Network Costs

- Network Expense = Operating Expense + Capital Depreciation
- Hardware Small Portion of Overall Network Expenses (~16%)



Economics: WWAN Network H/W Cost Breakdown

- WWAN Network Hardware Equipment Have the Same Cost Parameters
- All BTS Hardware Consists of:
 - Antenna
 - Power Amplifier
 - Cables
 - Rack
 - RF Cards
 - Digital Cards



• All WWANs Are Reducing Cost Through IP Based Architecture

- No Need for Legacy MSC Switches
- WWAN networks are moving towards IP cores (IMS, MMD)
- EV-DO, Rel.0, Rev. A and Rev. B are already IP-based networks

• All WWANs Controller Hardware Platforms Are Similar in Requirements and Cost

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More Sites Entail Higher Network Expenses

Lower Link Budget and Higher Frequencies Imply WiMAX Requires More Sites than WWAN Technologies



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 OUALCOMM

Performance: Higher Capacity Yields Lower Cost per Bit

Comparison of EV-DO, HSDPA, and WiMAX Sector Throughput



Simulation assumptions:

- 1 Full buffer; ITU channel models: pedA 3km/h 30%, pedB 10km/h 30%, vehA 30km/ 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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Assessing Wireless Broadband Options: Other Considerations



Broadband Services Often Require Additional Spectrum

- Spectral efficiency of latest technologies close to theoretical limit.
- Supplemental spectrum often needed for more broadband capacity, performance.

• All BWA Alternatives Face Same Challenges

- Trade-off always exists between range and throughput.
- Cheaper higher frequency spectrum has poorer propagation characteristics.
- Providing higher data rates usually entails greater cost.

Successful BWA Technologies Share Important Characteristics

- Enable compelling products and services, proven devices.
- Facilitate differentiating apps and services for mobile devices.
- Enjoy favorable spectrum allocation: allowing scale at specific frequency bands.
- Achieve standards compliance: facilitating proliferation of compatible devices.

PP and PP2 Solutions Are Sound Wireless Broadband Technology Options

They Meet the Criteria for Providing Sustainable, Economical Wireless Broadband

Significant Scale

- By 2009, WWAN technologies will combined,
 - approach 1 Billion subscribers
 - produce over \$500 Billion in service and equipment revenues
 - ship almost 900 Million WWAN devices annually

Broad and Mature Ecosystem

- Over 224 major operators
- After industry consolidation, over 30 major vendors

• Performance to Minimize Number of Sites

- Advanced techniques to continue to improve link budget
- Enhancements that yield greater spectral efficiency (capacity)

Successive PP/PP2 Releases Evolve Along Four Dimensions of Airlink Performance



Peak Data Rates:

 Achievable when user in optimal radio conditions

• User Data Rates:

- Avg data rate
- Cell edge data rate

• Quality of Service (QoS):

- Ability to prioritize apps/ flows
- Low and consistent latency
- Fast connection time
- Seamless mobility for delay sensitive apps

Capacity:

 Higher capacity allows more simultaneous users (lowers cost) and higher data consumption per user

End User Benefits



PP Evolution Offers Industry-leading O LIALCOVVV. Wireless Broadband Capabilities CDMA/TDM **OFDMA** Improvements to existing 5MHz carrier **Broadband Uploads** Increased Peak, Avg & Cell Edge Rates Reduced end to end • MIMO support delays • Enhanced capacity for real-time services Support for real-time Broadband Downloads S/W Upgrade Option services (VoIP) Backward Compatible • Reduced Delays on DL • MBMS Backward Compatible **Backward Compatible** Rel-5 HSDPA Rel-99 Rel-6 Rel-7 (Ph 1) Rel-8 (Ph 2) **WCDMA HSUPA** HSPA + (Evolution) LTE • OFDMA Deployments utilizing 5-20 MHz carrier BW Common FDD and TDD modes Enhanced capacity with advanced MIMO and SDMA support Higher Avg and Peak Data Rates Multimode devices provide seamless migration

PP2 Evolution Offers Industry-leading Wireless Broadband Capabilities



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Thank You











Appendix

Rel 5 - HSDPA



HSDPA Key improvements on downlink

- Shared channel transmission time, codes and power
- Higher order modulation 16 QAM
- Adaptive modulation and coding with Node B scheduling
- Hybrid ARQ with faster retransmissions

Increased capacity

- 300% gain in DL sector capacity

• Higher data rates

- DL peak data rates up to 7.2 Mbps (14.4 Mbps per standard)

• QoS

- Enables flow based QoS prioritization and multiple grades of service on downlink

• Enhanced services and applications

- Improves end-user experience for existing applications e.g. web browsing, VoD & MoD
- Enables mass marketing of applications such as place shifting of multimedia content, wireless video monitoring

Backward compatibility

- Allows new device capabilities to be introduced over time

Rel 6 - HSUPA



• HSUPA Extends benefits of HSDPA to uplink

- Fast Uplink Scheduling
- Fast and efficient re-transmission (HARQ) on uplink
- Shorter transmission time interval (TTI) on uplink

Increased capacity

- 80% gain in UL sector capacity

• Higher data rates

Provides UL peak data rates of up to 5.76 Mbps

• QoS

- Enables flow based QoS prioritization and multiple grades of service on uplink

• `Enhanced services and applications

- Improves end-user experience UL intensive applications (sending files, picture/video messaging)
- Low latency networked gaming
- Enables mass marketing of applications such as mobile social networking, embedded consumer electronics
- Enables efficient multicast transmission (MBMS)

Backward compatibility

- Allows new device capabilities to be introduced over time

HSPA+



• HSPA+ continues evolution of WCDMA and provides best in class performance in a 5MHz carrier

- Enhanced UE receiver performance requirements
 - Inter-cell interference reduction for improved edge of cell performance

Increased capacity

- Increased System Capacity : 2X Release 6 DL Capacity and 4X Release 6 UL Capacity

• Higher Data Rates

- Higher Data Rates: 3X Release 6 DL Peak Rates and 2X Release 6 UL Peak Rates
- Increased peak rate in high SNR scenarios MIMO

• Enhanced support for data services

- Reduced set-up times, enhanced support for real time services (Packet VT, VoIP and enriched V+D applications)
- Improved performance in "active state"

• Backward compatible

- Continued support for Rel. 99 and HSPA terminals

LTE (Long Term Evolution)

New air interface

- OFDMA in DL and SC-FDMA in UL
- Same principles as HSPA+ : Link Adaptation, HARQ, MIMO, etc.

Flexible bandwidth and modes

- Variable bandwidths (note Samir stated not to put 1-20 MHz, work in progress)
- Wider bandwidths (5-20 MHz)
- Asymmetric bandwidth allocation in uplink / downlink
- Flexible duplex modes -FDD, TDD and FDD half duplex
- High peak rates 100 Mps DL/50Mbps UL in 20MHz
- Enhanced control of inter-cell interference and cell edge coverage
 - Increased cell edge data rates
- Enhanced broadcast (MBMS) support
- Multimode devices provide seamless migration

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EV-DO Rev A



Key Improvements

- Designed for symmetric traffic
- Reduced latency and optimized QoS enables delay sensitive applications

Increased capacity

- 1.2 times Rel 0 forward link sector capacity
- 3.4 times Rel 0 reverse link sector capacity

• Higher data rates

- 3.1 Mbps peak data rate on forward link
- 1.8 Mbps peak data rate on reverse link

• Enhanced services and applications

- Greatly improved end-user experience for applications such as sending email attachments, pictures and videos
- Support for new delay sensitive applications Push to Talk, Video Telephony, Instant Multi-Media (IMM), VoIP, enriched V+D applications, and low delay gaming
- DO Platinum Multicast

Backward compatibility

Continued support for existing Rel 0 devices

EV-DO Rev B



Key Improvements

- Aggregates multiple carriers for higher performance
 - 5MHz initial configuration

Higher spectral efficiency

Improved on both FL and RL due to Multi-carrier TX

Higher data rates

- Linear gains in peak rates
 - 2 RFs 6.2 Mbps*, 3 RFs 9.3 Mbps

• Enhanced services and applications

- Mobile broadband experience across entire coverage area
- Similar user experience across mobile and fixed networks
- Higher streaming rate for video and music
- Faster download of higher quality, longer video and music
- Faster upload of pictures, video and audio files (social networks, blogs)
- Faster mobile broadband for laptops

Backward compatibility

- Continued support for existing Rev A devices
- Software upgrade option to existing DOrA channel cards

EV-DO Rev C

- Highly optimized Mobile OFDMA solution with significantly higher
 performance than competing technologies
 - Advanced antenna techniques
 - Superior interference management
 - Optimized reverse link

BW = 10 MHz, FDD	1 X N	2 X N	4 X N
FL	37 Mbps	70 Mbps	140 Mbps
RL*	34 Mbps	N/A	

M x N: M tx antennas ,N rx antennas

- Scalable IP network architecture and advanced QoS mechanisms enable leading-edge performance
 - Excellent support for real time services (e.g., VoIP)
 - Seamless handoffs to same or different technologies
- Enhanced user experience with higher data rates (peak, avg, cell edge), lower latency, and seamless mobility
- More flexible and affordable services with higher capacity and robust QoS capabilities
- Support for all applications ranging across handsets, Smartphones/ PDAs, Laptops, Desktops, and CE platforms