Wireless Communications: Perspectives on the State of the Technology and Where it Is Going

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April 27, 2007
Wireless Communications: Perspectives on the State of the Technology and Where it Is Going

- Some business and economic perspectives
- Air interface evolutions
- Wireless computing
- MediaFLO
Nearly one third of the world population has a cell phone.
3G Economies Are Huge

Total 3G Subscribers Worldwide (2005 - 2011)

- WCDMA (includes HSDPA, HSUPA, etc.)
- CDMA2000 (includes 1x, Rev A, Rev B, etc.)
- Fixed & Mobile WiMAX

Worldwide Service and Equipment Revenue, 2009

- Service Revenue
- Equipment Revenue

Sources:
1. WCDMA & CDMA2000 1xEV-DO: Blended forecast from iGR (Feb 06), Strategy Analytics (Jan 06), Wireless Intelligence (July 06) and Yankee Group (June 06)
2. WiMAX: Blended forecast from Strategy Analytics (June 06) and ABI (Q2 06), Maravedis (Sept 06)

Global Handset Shipments by Technology (2004 - 2011)

Source: Deutsche Bank, "At the starting line – The race to mobile broadband", 2 February, 2007
Data Is a Steadily Growing Share of Operator Revenues

**Operator Voice and Data Revenues (2005 - 2010)**

Source: Informa Telecoms & Media, “Mobile Content and Services”, June, 2006
Data ARPU Growing Gradually as Voice ARPU Declines

Global Voice and Data ARPU (2005 - 2010)

Source: Informa Telecoms & Media, “Mobile Content and Services”, June, 2006
Data: Go After Things that Are Important

• Make cost/bit low
  – Low cost/bit permits low price which drives usage
  – Spectrum is expensive

• Provide coverage

• Keep delay low

• Provide minimum quality of service (move towards nearly equal grade of service)

• Handoff that works

• It’s more than about air interfaces

• Have clear migration strategy

• Have clean integration with existing deployments

• Provide clear performance and end customer benefit

• Make it easier to deploy

• Provide always on (continuous computing)

• Keep complexity under control
- Advanced QoS - VoIP, VT, PTT, E-mail, Instant Messaging
- Broadband Downloads
- OFDM introduced for multicast
- Backward Compatible
- Multi-carrier Rev A (Up to 5MHz carrier BW)
- Best in class performance in 5 MHz
- Improved Peak, Avg & Cell Edge Data Rates
- Improved user experience (lower delays, consistent high data rates)
- S/W Upgrade
- Backward compatibility with legacy devices

** Ultra Mobile Broadband - Previously referred to as Rev C LBC

9/26/06

* Standard supports up to 20 MHz

** Ultra Mobile Broadband - Previously referred to as Rev C LBC

CDMA2000
1X

CDMA2000
1xEV-DO

REV-DO
Rev. A

REV-DO
Rev B*

UMB**
The Evolution of 1x and 1xEV-DO Peak Rates in 1.25 MHz

1x standards support higher rates; 153.6 kbps is maximum deployed rate
2 64-QAM modulation modes are optional; when supported also used for data rate < 3.07 Mbps
3 Peak rates for Rev B Nx are N times single channel peak rates
Sprint Northeast 1xEV-DO Rev A Coverage

1x: Clear voice and data service

1xEV-DO: Broadband download speeds

1xEV-DO Rev A: Increased broadband download and upload speeds

Source: Sprint website
3GPP2 UMB (Ultra Mobile Broadband)

- **Spectrum flexibility**
  - Bandwidths from 1 to 20 MHz
  - Support for FDD, half duplex FDD and (in future, TDD modes)
  - Supports 450 MHz to 3.6GHz

- **OFDMA DL; OFDMA UL**

- **Support for spatial techniques**
  - Single user MIMO (DL/UL)
  - Multi user MIMO (DL/UL)
  - Up to 4x4 MIMO (DL)
  - SDMA / Beam forming

- **Data scheduling efficiency**
  - Support for time and frequency domain scheduling
  - Ability to trade capacity for edge of cell service quality through fractional frequency re-use

- **High peak rates & low latency**
  - Up to 291 Mbps peak DL rate
  - Up to 79 Mbps peak UL rate
  - Very low latency

- **Efficient broadcast modes**
  - SFN broadcast

- **Evolved Packet Core**
  - 2 Node architecture
  - Lower control delays
  - Simple QoS model
  - Enhanced support for mobility and service continuity across various access technologies.
1 – 14.4 Mbps supported in standard, incremental product release expected

2 – Upper range for DL peak rates includes 64 QAM and 2x2 MIMO (Rel 7)

3 – 20 MHz, FDD, 64-QAM, 4x4 MIMO in DL and 16 QAM, 1 TX in UL.

4 – 2x2 MIMO

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### 3GPP Broadband Evolution Path

**WCDMA**
- **Rel-99**
  - DL: 384 kbps peak
  - UL: 384 kbps peak

**HSPA**
- **Rel-5 (HSDPA)**
  - DL: 1.8-14.4 Mbps peak
  - UL: 384 kbps peak
- **Rel-6 (HSUPA)**
  - DL: 1.8-14.4 Mbps peak
  - UL: 5.72 Mbps peak

**HSPA +**
- **Rel-7 (Ph 1)**
  - DL: 28 Mbps peak
  - UL: 11 Mbps peak
- **Rel-8 (Ph 2)**
  - DL: TBD
  - UL: TBD

**LTE**
- **Rel-99**
  - OFDMA in DL
  - SC-FDMA in UL
  - Flexible carrier bandwidths up to 20MHz
  - Common FDD & TDD modes
  - Higher order MIMO/SDMA

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1 – 14.4 Mbps supported in standard, incremental product release expected

2 – Upper range for DL peak rates includes 64 QAM and 2x2 MIMO (Rel 7)

3 – 20 MHz, FDD, 64-QAM, 4x4 MIMO in DL and 16 QAM, 1 TX in UL.

4 – 2x2 MIMO
3GPP LTE/SAE Capabilities

- **Spectrum flexibility**
  - Bandwidths from 1 to 20 MHz
  - Support for FDD, half duplex FDD and TDD modes

- **OFDMA DL; SC-FDMA UL**

- **Support for spatial techniques**
  - Single user MIMO (DL/UL)
  - Multi user MIMO (DL/UL)
  - Up to 4x4 MIMO (DL)
  - SDMA / Beam forming

- **Data scheduling efficiency**
  - Support for time and frequency domain scheduling
  - Ability to trade capacity for edge of cell service quality through fractional frequency re-use

- **High peak rates & low latency**
  - Up to 300 Mbps peak DL rate
  - Up to 75 Mbps peak UL rate
  - Down to 10 ms TCP RTT

- **Evolved Packet Core (EPC)**
  - 2 Node architecture
  - Lower control delays
  - Simple QoS model
  - Enhanced support for mobility and service continuity across various access technologies.

- **Efficient broadcast modes**
  - SFN broadcast
  - Stand-alone broadcast
Deployment scenario 1: 2GHz, 500m site-to-site, 20 dB penetration, TU, 3 km/hr, best effort
Deployment scenario 1: 2GHz, 500m site-to-site, 20 dB penetration, TU, 3 km/hr, best effort
3G Mobile Network Expense – High Data Usage

- **600 MOU /Sub/Month**
- **1000 MByte /Sub/Month**

Both OpEx and CapEx are driven by number of cell

**Notes:**
- Urban morphology (10K Pops/SqKm)
- Wireless penetration: 50%
- Operator market share: 25%
- Local call termination charges and long distance transport costs are not included in the network expense calculations
- Spectrum available: 2X10MHz @ 800MHz
Wireless Computing

It's more than just 802.xx
Many Embedded Mobile 3G Broadband Solutions

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*Sum of individual notebooks certified per carrier network
Integrated 3G Wireless Module Forecasts

“We anticipate 16.4 million total units will ship in 2011. By that time, embedded modems as a percentage of shipments will have grown from 20% to 60%.” - Strategy Analytics, January 2007
• The integration and coexistence of WWAN radios with other “noisy” electronics brings about new set of EMI considerations.

**Conducted Verus Radiated Receiver Sensitivity**

**Cellular Band-Channel 777 (893.31MHz)**

-110 -105 -100 -95 -90 -85 -80 -75 -70 -65 -60

- **Laptop A**
- **Laptop B**
- **Laptop C**
- **Laptop D**

PC card in laptop.

Entire laptop/card assembly tested as a single unit.

Radiated tests are conducted with laptop streaming video to display.
Antenna Placement Study

- **Evaluated performance of various antenna types at various laptop locations**
  - Key antenna performance metrics evaluated for each location and type

- **Prototypes built and integrated on a test laptop in the antenna range and in realistic network conditions**
  - Correlate measured antenna performance metrics to field performance parameters

Body Interaction Evaluation
Pattern Performance vs. Antenna Location

Antenna embedded in lower Base

Antenna integrated in upper LCD

V-pol

H-pol
Consumers Desire Mobile Video Services

Source: Primary research results conducted by Spear & Associates, sample of 2,800 cell phone and cable users and nationwide focus groups.

- Preference for mobile video service second only to voice
  - 1.5 to 1 preference for video service over camera-phone
  - 2.3 to 1 preference for video service over push-to-talk

Source: Primary research results conducted by Spear & Associates, sample of 2,800 cell phone and cable users and nationwide focus groups.
Forecasts Show Significant Growth for Mobile TV

Worldwide mobile TV subscribers slated to expand

Estimates from ABI, Informa, In-Stat, iSuppli, Datamonitor, NSR, Strategy Analytics, IMS Research, Mobile Youth, eMarketer, and Juniper.
What MediaFLO Will Offer Customers

- **Subscription-based service**
- **QVGA live streaming video, up to 30 frames per second**
- **Clipcasting™ – network scheduled media**
- **Datcasting**
- **Interactive services for two-way exchange**
Subscription-Based Mobile Media Service

- Service is based on a simple subscription model
  - User receives keys for the subscribed services
Clipcasting™ – Network Scheduled Media

- Network scheduled delivery of programmed media
- Device memory management
- Users subscribe to packages of program channels
- MediaFLO program guide contains file description information and distribution window
  - Maximizes battery savings, minimizes file acquisition time, saves air link bandwidth
- Single channel protocol – no additional overhead

Diagram:
- CAA WorldNews Tonight
- Presentation Time
- Distribution Window indication in Program Guide to enable power savings
Key MediaFLO Technical Characteristics

- **5, 6, 7, and 8 MHz channels**
- **OFDM with FFT size = 4096 subcarriers**
  - The 4096 subcarriers span 5.42 MHz (6 MHz)
  - 96 guard subcarriers (48 on one side of the band, 47 on the other side, and DC) in which no power is radiated.
    - In each OFDM symbol, 4000 modulation symbols (data or pilot) can be transmitted.
    - The inter-subcarrier spacing is 1.355 kHz
- **QPSK or 16-QAM is used on each subcarrier**
- **OFDM symbol duration is 740.7 microseconds; cyclic prefix is 92.6 microseconds**
- **Divide 4000 modulation symbols into 8 interlaces**
  - Symbols from each interlace are spread across the bandwidth
  - One interlace carries pilots (which changes from symbol to symbol)
  - Handset needs to only demodulate interlaces it needs
- **Single Frequency Network**
- **The basic unit of data transmission at the physical layer is a 1000-bit physical layer packet (PLP) that includes a 16-bit CRC**
- **Error correction coding**
  - There is an (N, K) outer Reed-Solomon code with N=16 and K=12,14, or 16
  - Parallel concatenated turbo code with code rates of 1/3, ½, and 2/3 are used

For details: see TIA-1099
US MediaFLO Network

- The MEDIAFLO USA DEDICATED MULTICAST NETWORK
  - Deploys and operates the network for wireless carriers

- Delivered through the 700 MHz spectrum, UHF Channel 55
- Each site has approx. 50,000 watts EIRP – enabling coverage to a large metropolitan area with just a few (1-7) transmitters

- Verizon Wireless is currently providing commercial service
- Cingular has announced that they will be providing service