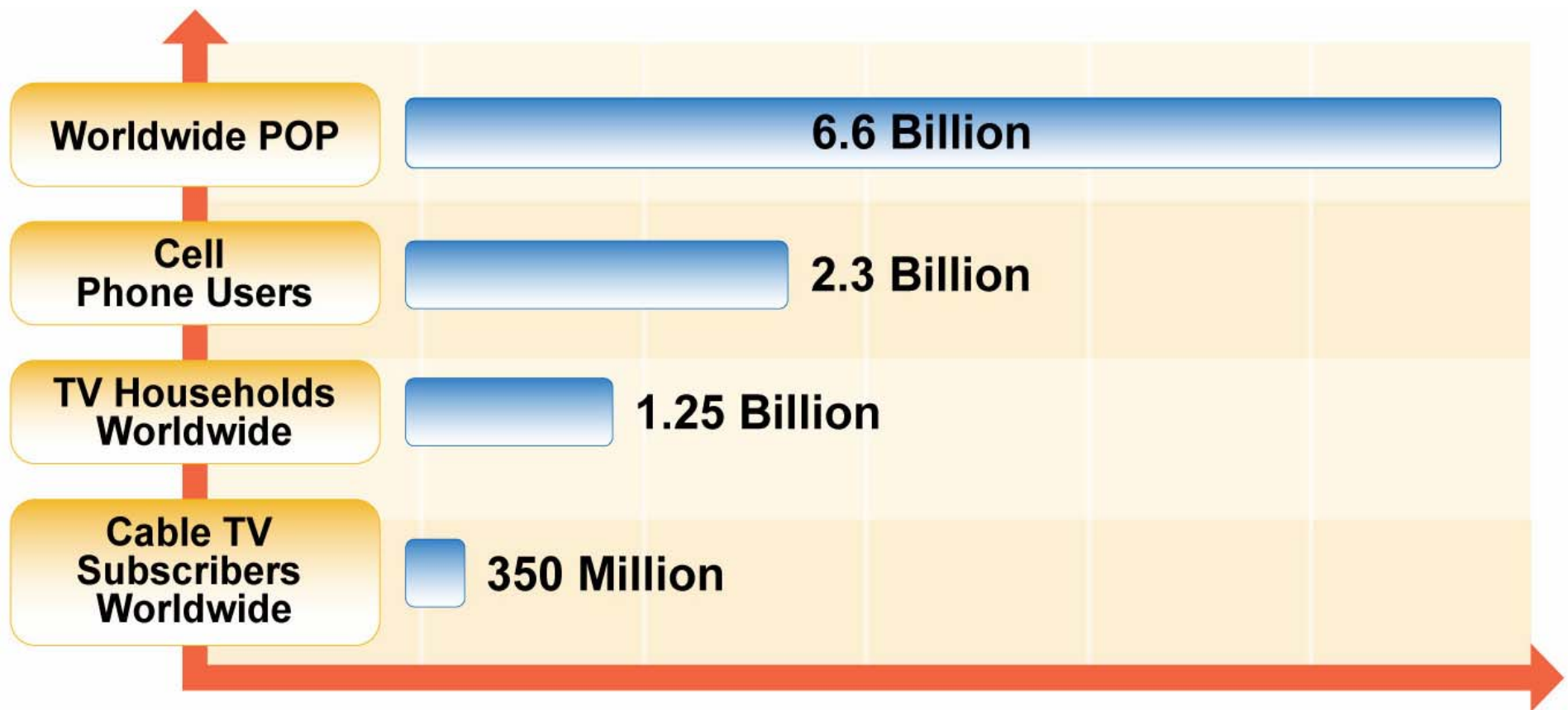


Wireless Communications: Perspectives on the State of the Technology and Where it Is Going



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

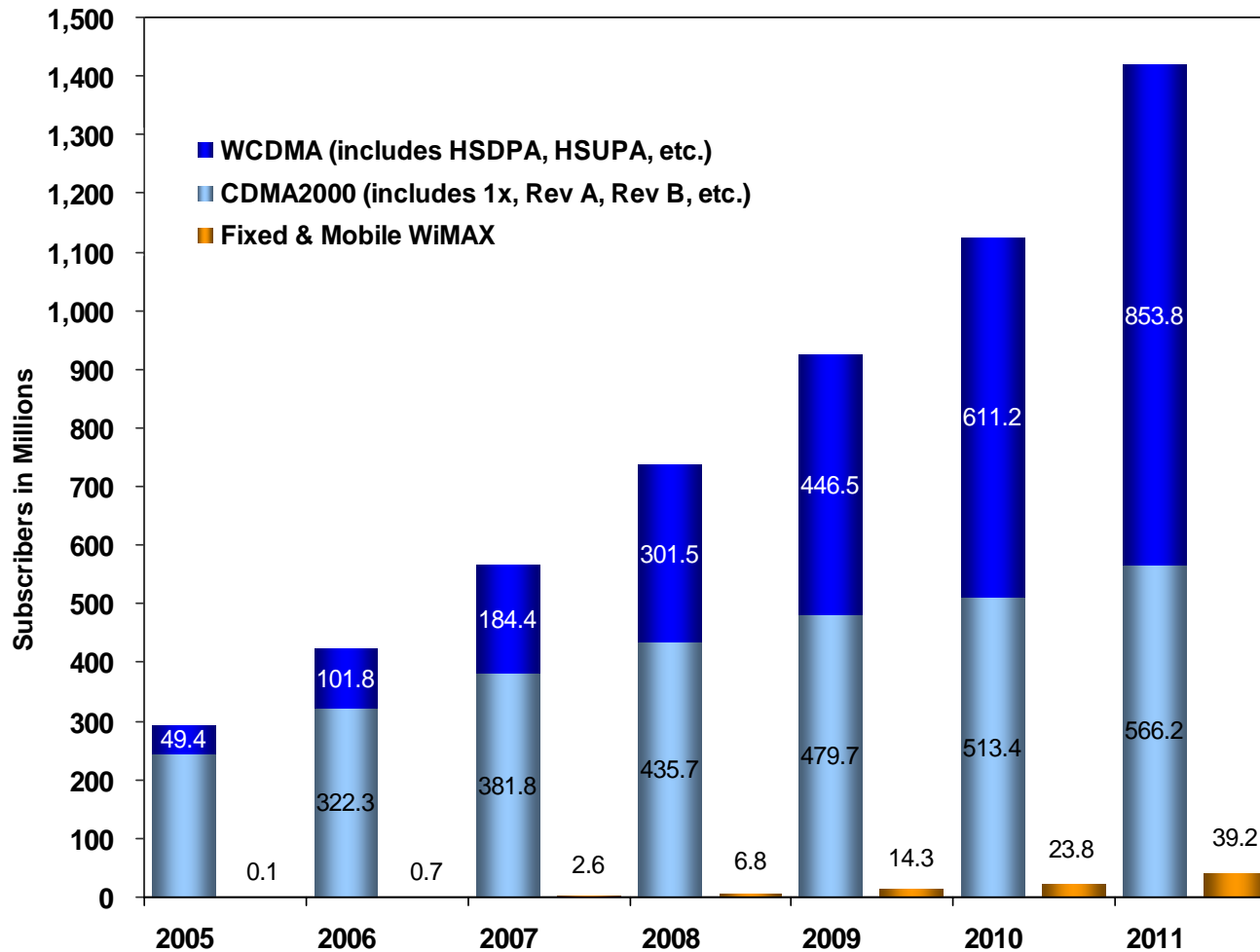
- *Some business and economic perspectives*
- *Air interface evolutions*
- *Wireless computing*
- *MediaFLO*



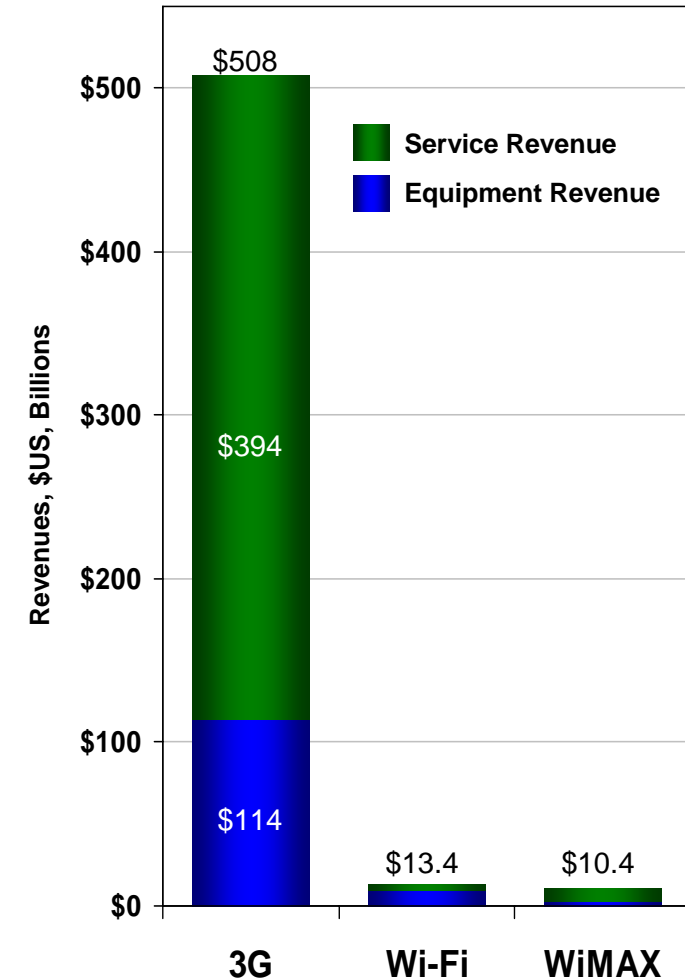
Nearly one third of the world population has a cell phone.

3G Economies Are Huge

Total 3G Subscribers Worldwide (2005 - 2011)



Worldwide Service and Equipment Revenue, 2009



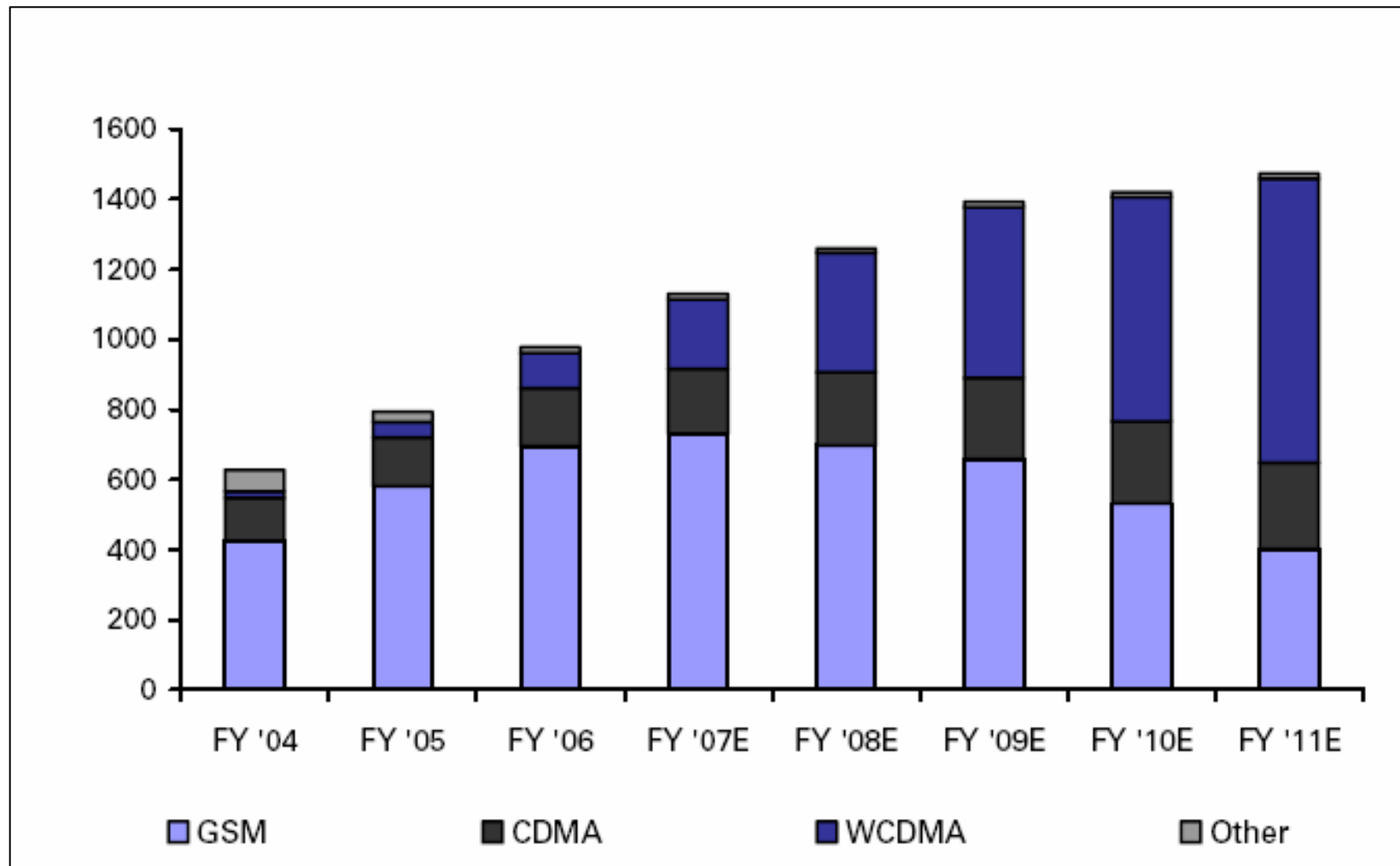
Sources:

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)

1. Strategy Analytics (2006)
2. Average of Strategy Analytics and Yankee Group forecasts (2006)
3. Forward Concepts (2005)
4. Average of Strategy Analytics (2006), Gartner (2006) and Forward Concepts (2005)

3G Device Scale Growing Rapidly

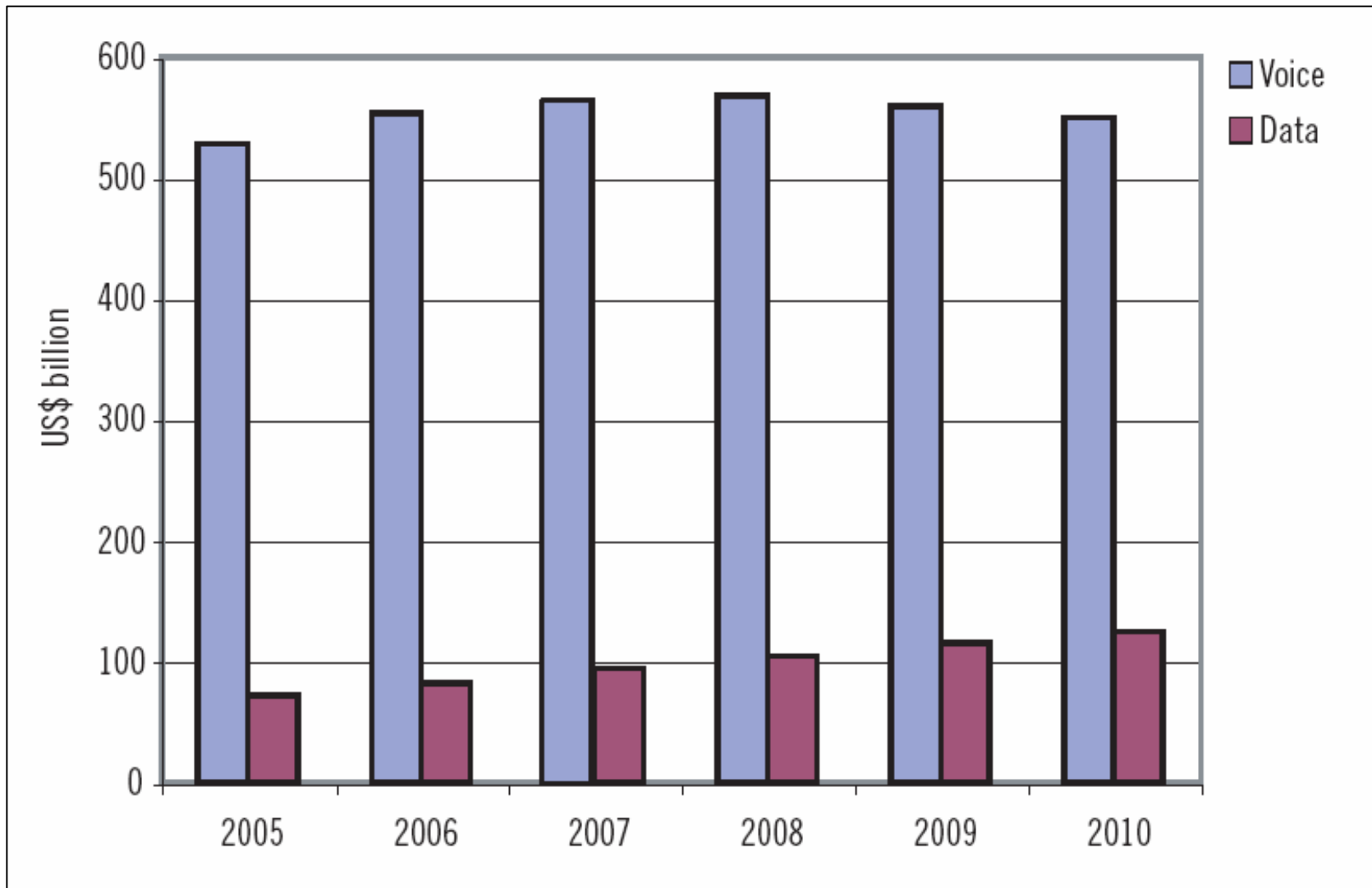
Global Handset Shipments by Technology (2004 - 2011)



Source: Deutsche Bank, "At the starting line – The race to mobile broadband", 2 February, 2007

Data Is a Steadily Growing Share of Operator Revenues

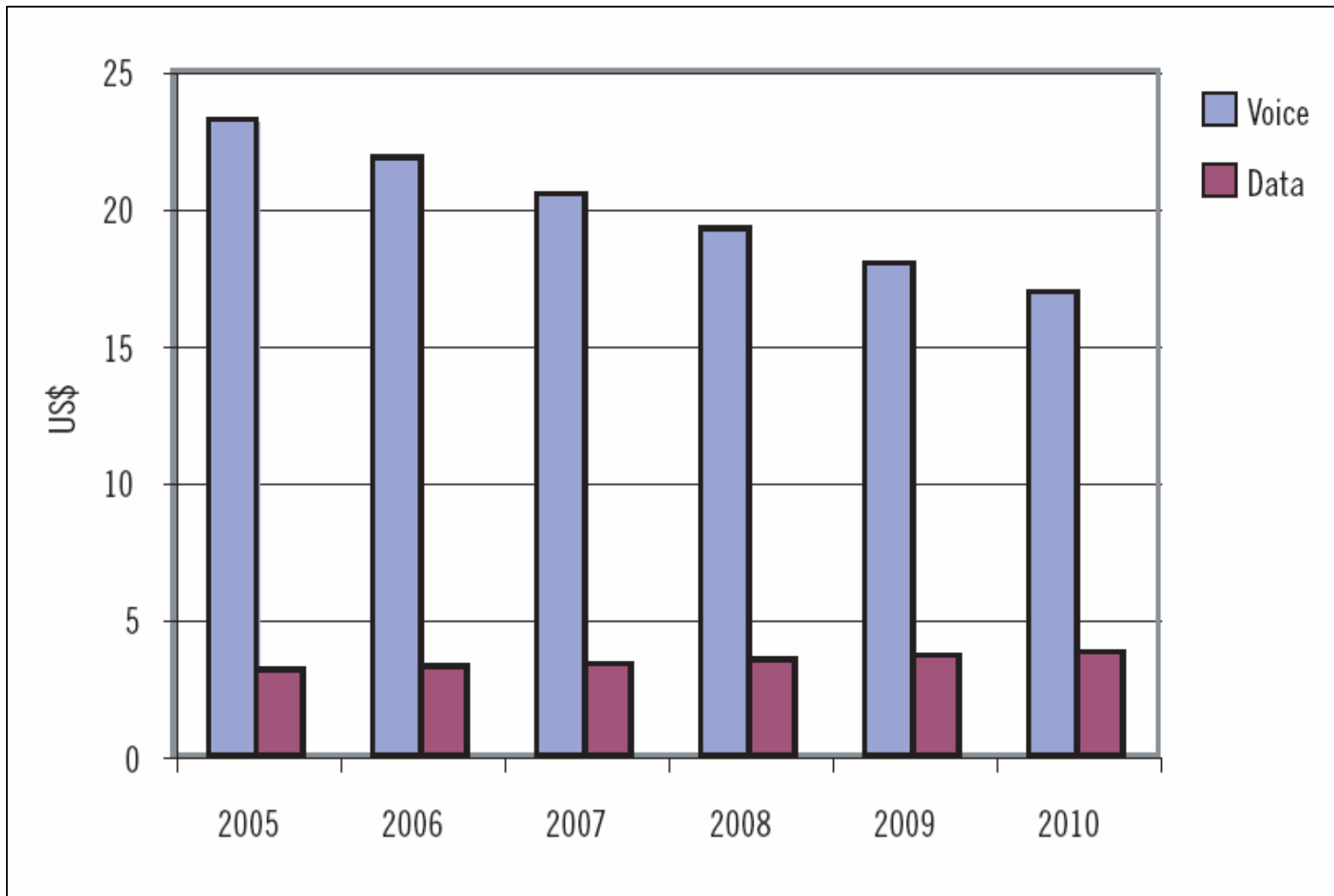
Operator Voice and Data Revenues (2005 - 2010)



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

- *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*
- *Its 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*

3GPP2 Broadband Evolution Path

CDMA CDMA/TDM OFDM OFDMA

- All-IP Services
- Broadband Downloads

- Advanced QoS - VoIP, VT, PTT....
- Broadband Uploads
- 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

CDMA2000
1X

CDMA2000
1xEV-DO

EV-DO
Rev. A

EV-DO
Rev B*

UMB**

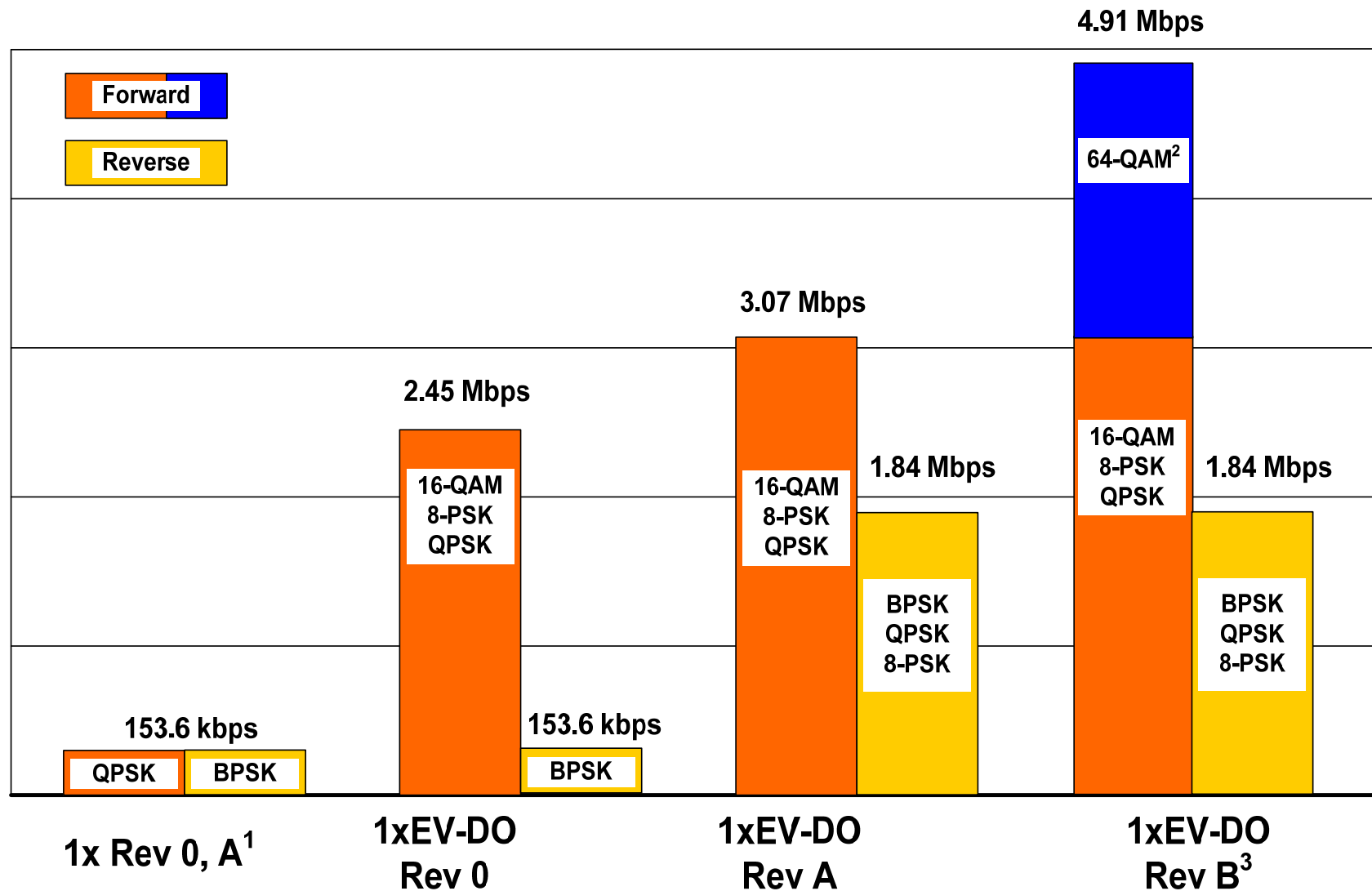
- Highly optimized OFDMA solution
- Support for flat network architecture
- Deployments utilizing 5-20 MHz carrier BW
- FDD and TDD modes
- More capacity with wider carrier bandwidth, advanced MIMO and SDMA support
- Higher Avg & Peak Data Rates (wider carrier bandwidth, advanced MIMO)
- Multimode devices provide seamless migration

* Standard supports up to 20 MHz
** Ultra Mobile Broadband -
Previously referred to as Rev C LBC

9/26/06

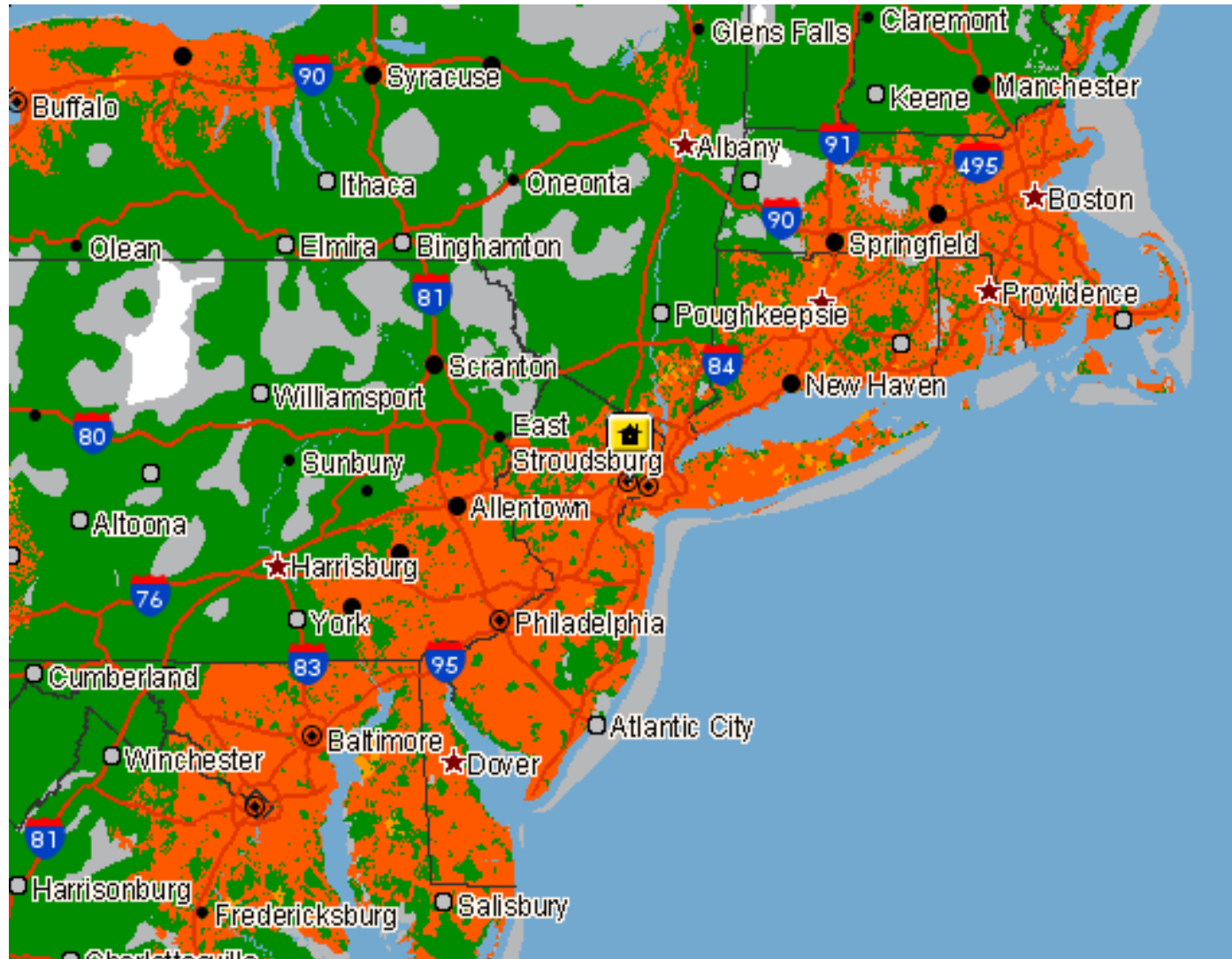
2006 2007 2008 2009 2010+




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



- 1 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



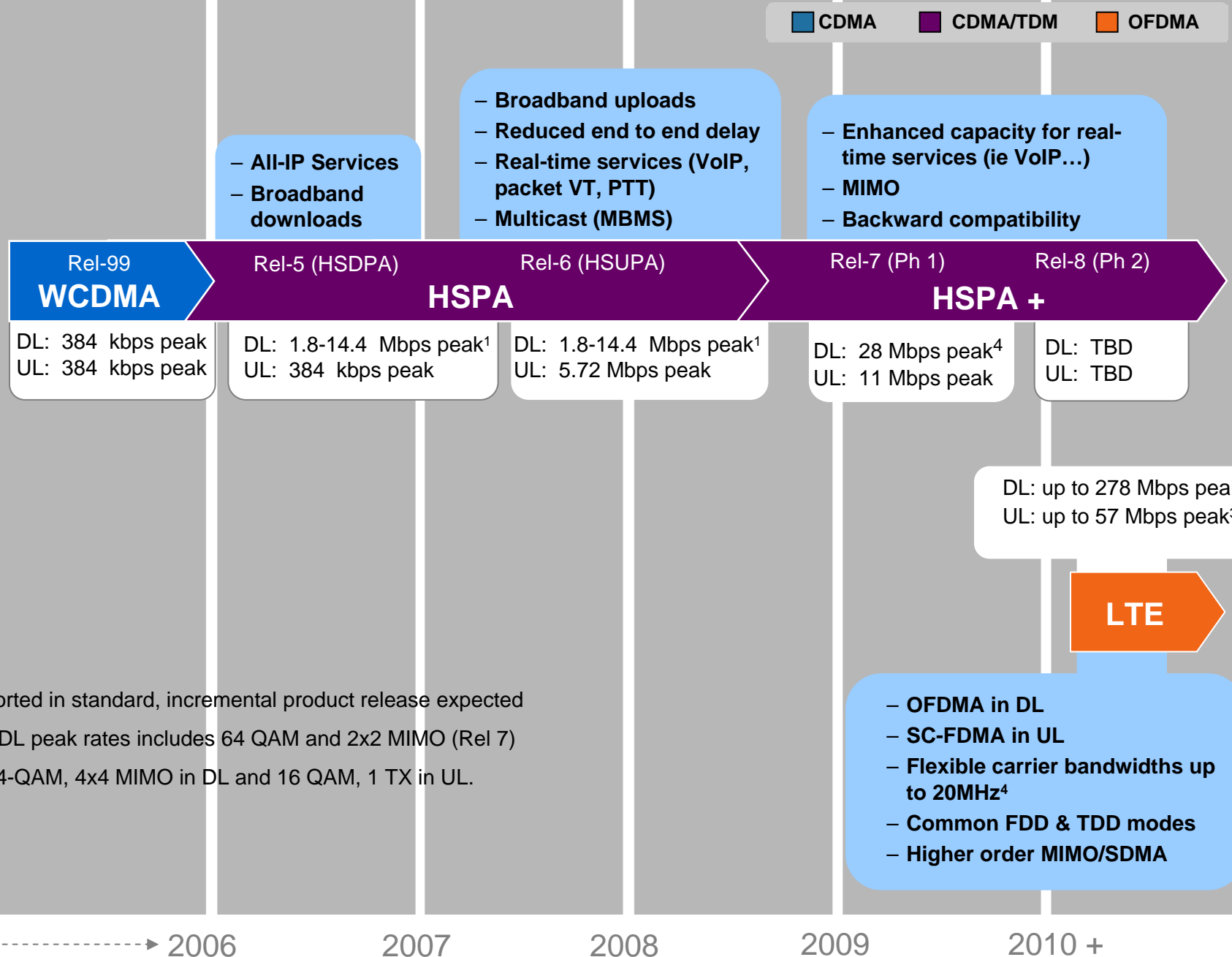
-  **1x: Clear voice and data service**
-  **1xEV-DO: Broadband download speeds**
-  **1xEV-DO Rev A: Increased broadband download and upload speeds**

Source: Sprint website



- ***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.

3GPP Broadband Evolution Path

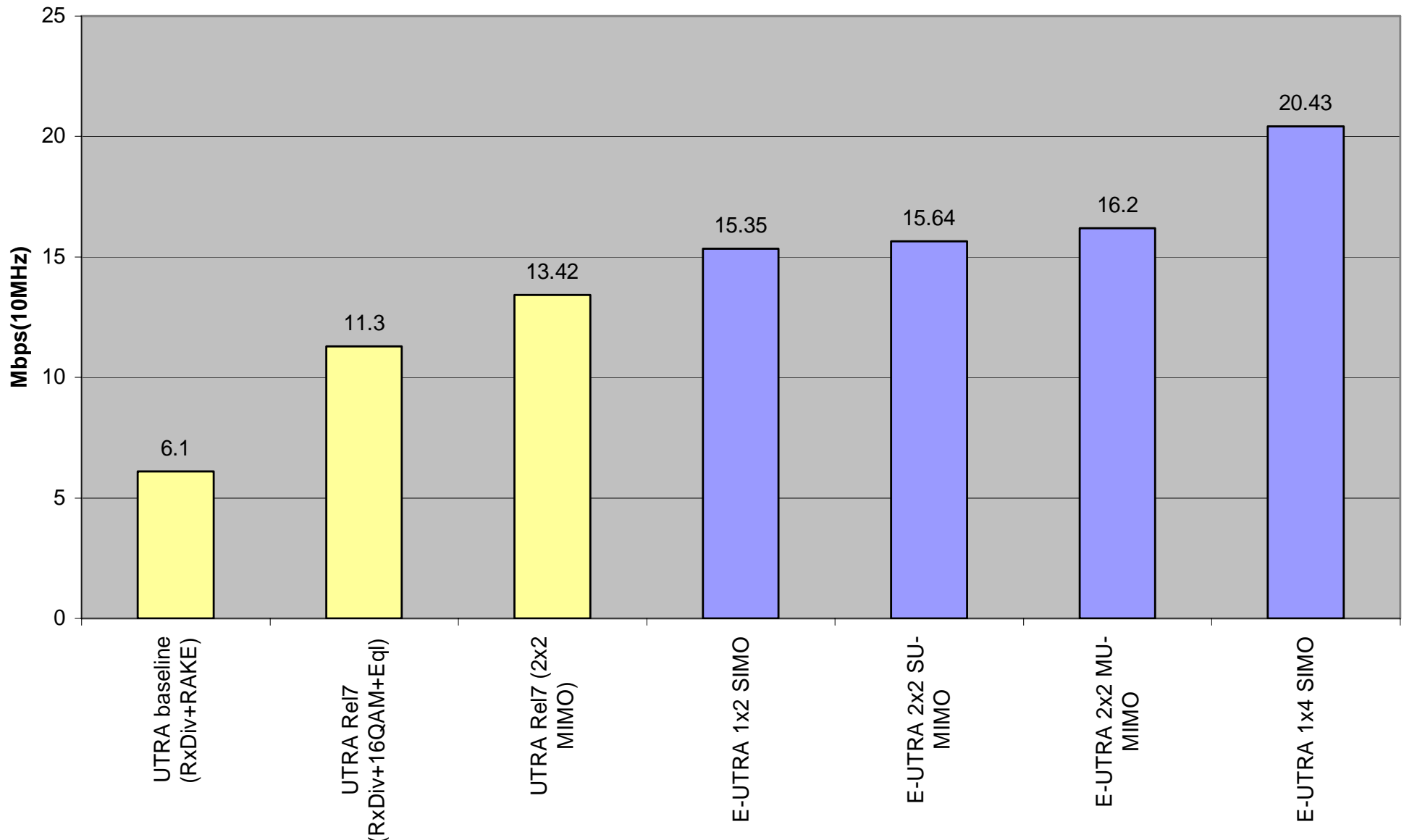


- 1 – 14.4 Mbps supported in standard, incremental product release expected
- 2 – Upper range for DL peak rates includes 64 QAM and 2x2 MIMO (Rel 7)
- 3 – 20 MHz, FDD, 64-QAM, 4x4 MIMO in DL and 16 QAM, 1 TX in UL.
- 4 – 2x2 MIMO

- ***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

Average DL Sector Throughput for 3GPP

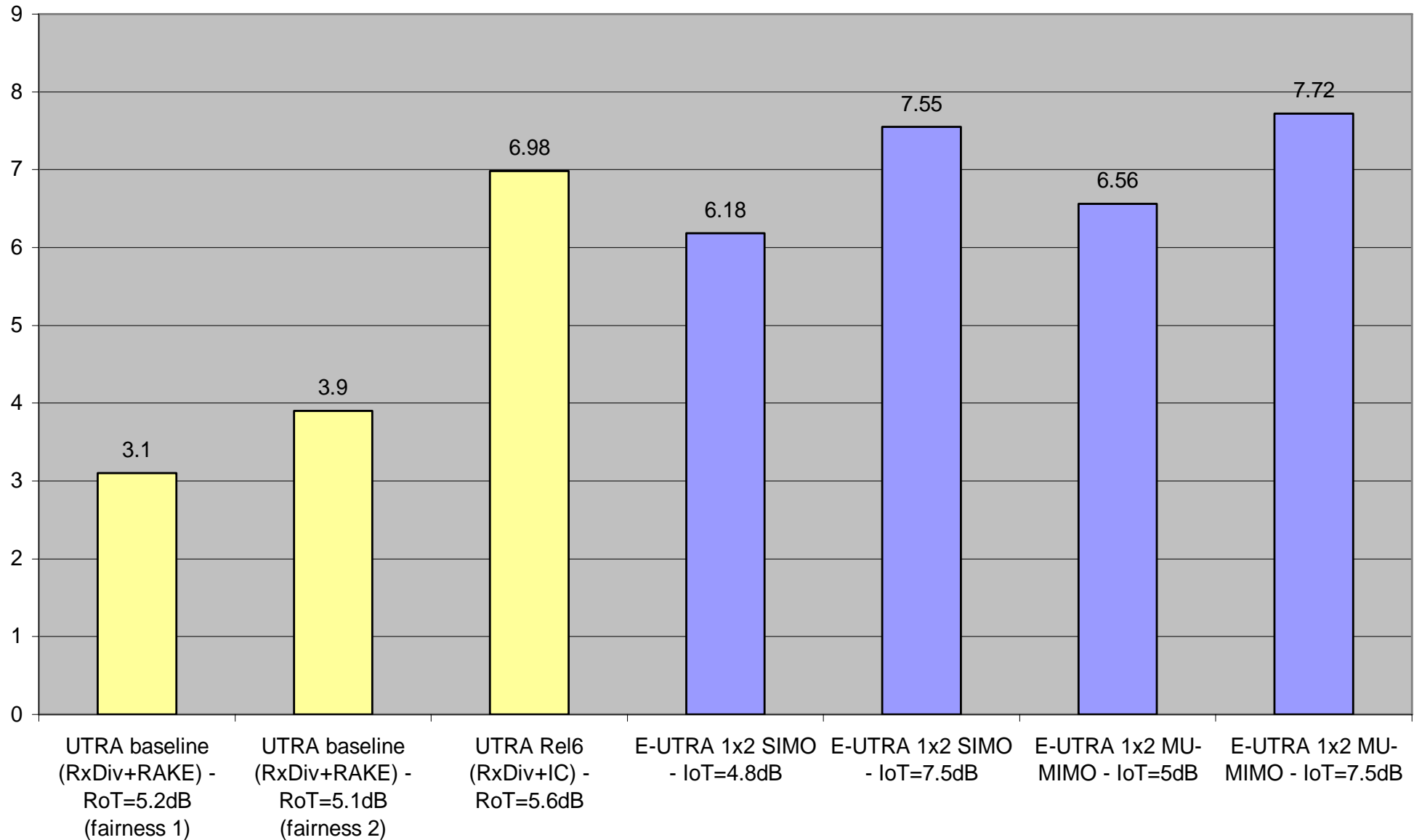
D1 - DL Performance Characterization - Full Buffer Traffic
Average Sector Throughput



Deployment scenario 1: 2GHz, 500m site-to-site, 20 dB penetration, TU, 3 km/hr, best effort

Average UL Sector Throughput for 3GPP

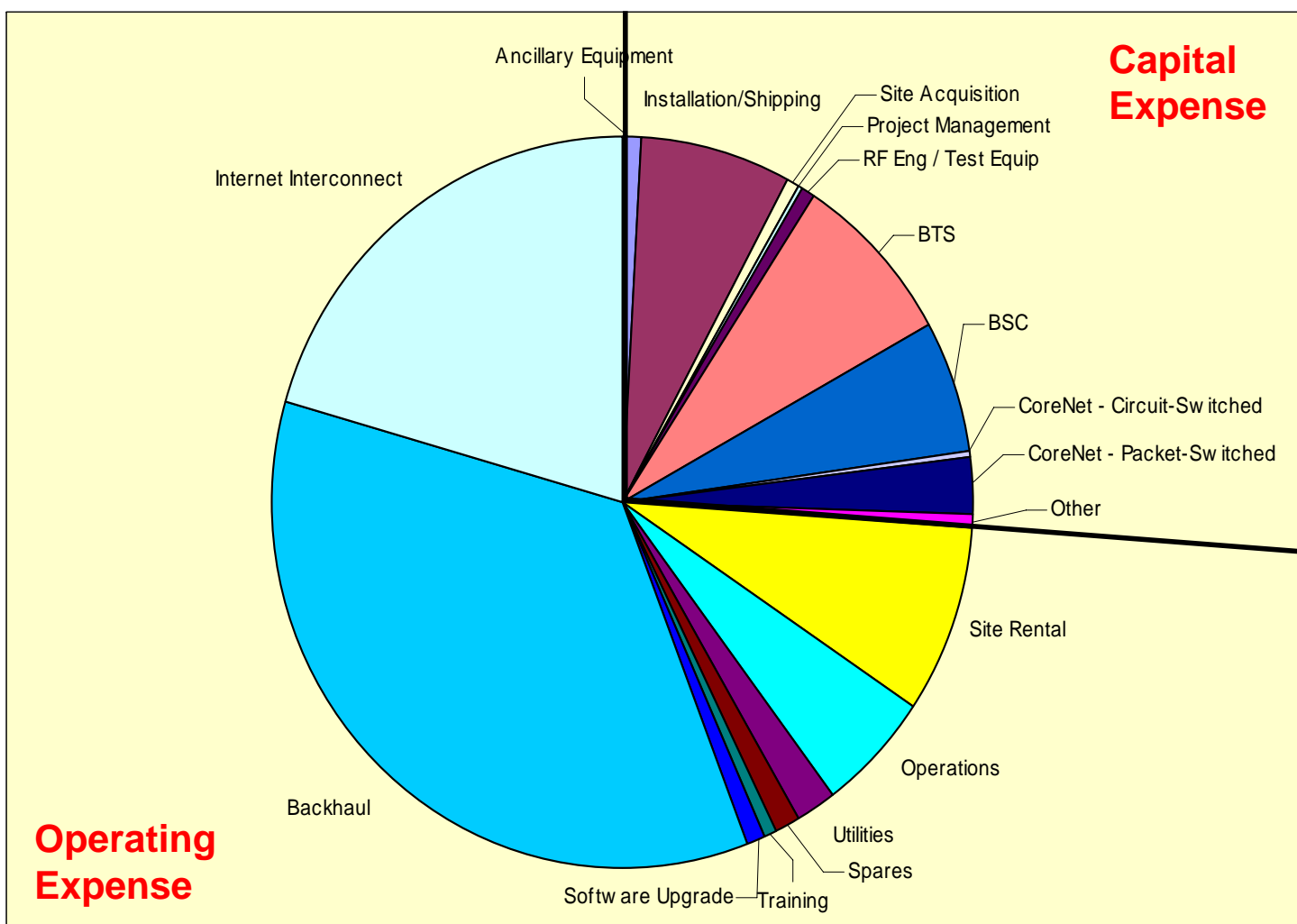
D1 - UL Performance Characterization - Full Buffer Traffic
Average Sector Throughput



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



Seven-Year Depreciated Capital (% of Total Network Expense)	26%
Ancillary Equipment	1%
Installation/Shipping	7%
Site Acquisition	1%
Project Management	0%
RF Eng / Test Equip	1%
BTS	8%
BSC	6%
CoreNet - Circuit-Switched	0%
CoreNet - Packet-Switched	3%
Other	0%
Operating Expense (% of Total Network Expense)	74%
Site Rental	8%
Operations	5%
Utilities	2%
Spares	1%
Training	1%
Software Upgrade	1%
Backhaul	35%
Internet Interconnect	20%

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

Both OpEx and CapEx are driven by number of cell

Wireless Computing

Its more than just 802.xx



Many Embedded Mobile 3G Broadband Solutions



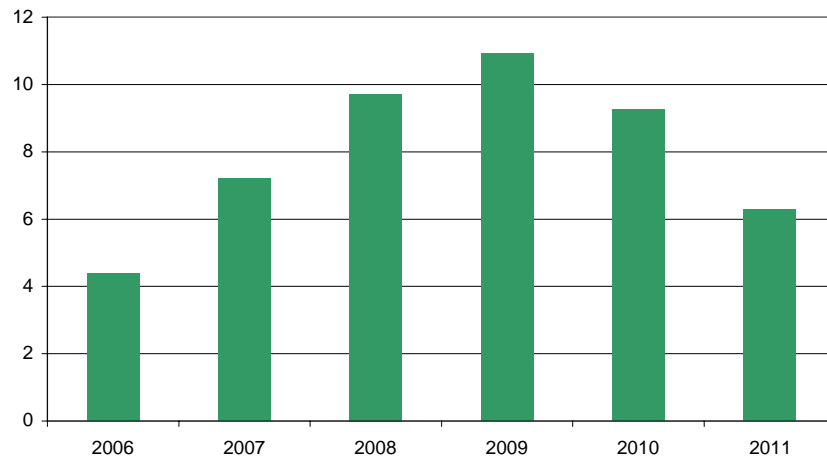
March 2006	March 2007
21	98*
Launched NB Offerings	
11	45
Launched NB Models	
5	16
Notebook Manufacturers	
4	17
3G Embedded Carriers	

*Sum of individual notebooks certified per carrier network

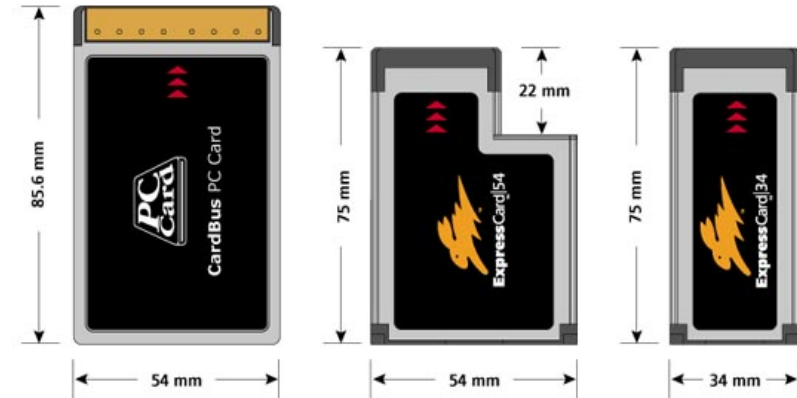
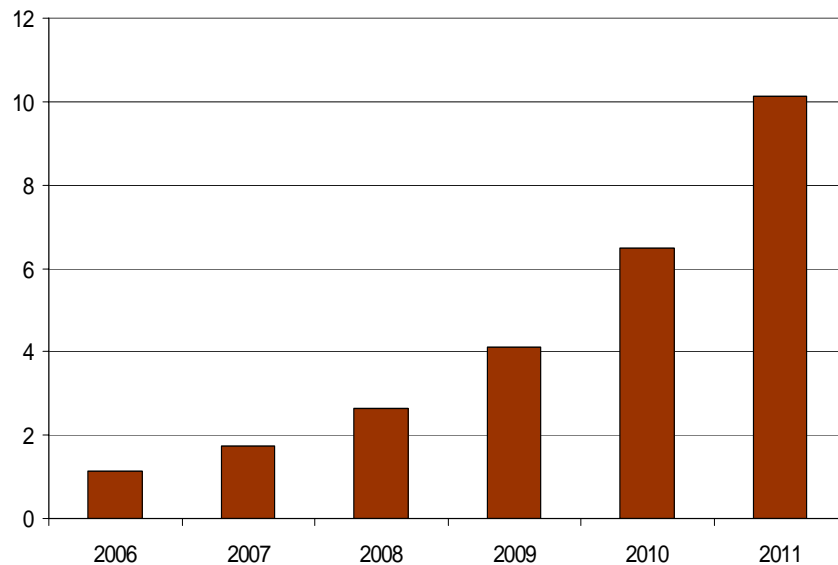


Integrated 3G Wireless Module Forecasts

Global PC Card Unit Sales forecast (M)



Global Integrated Modem Sales forecast (M)



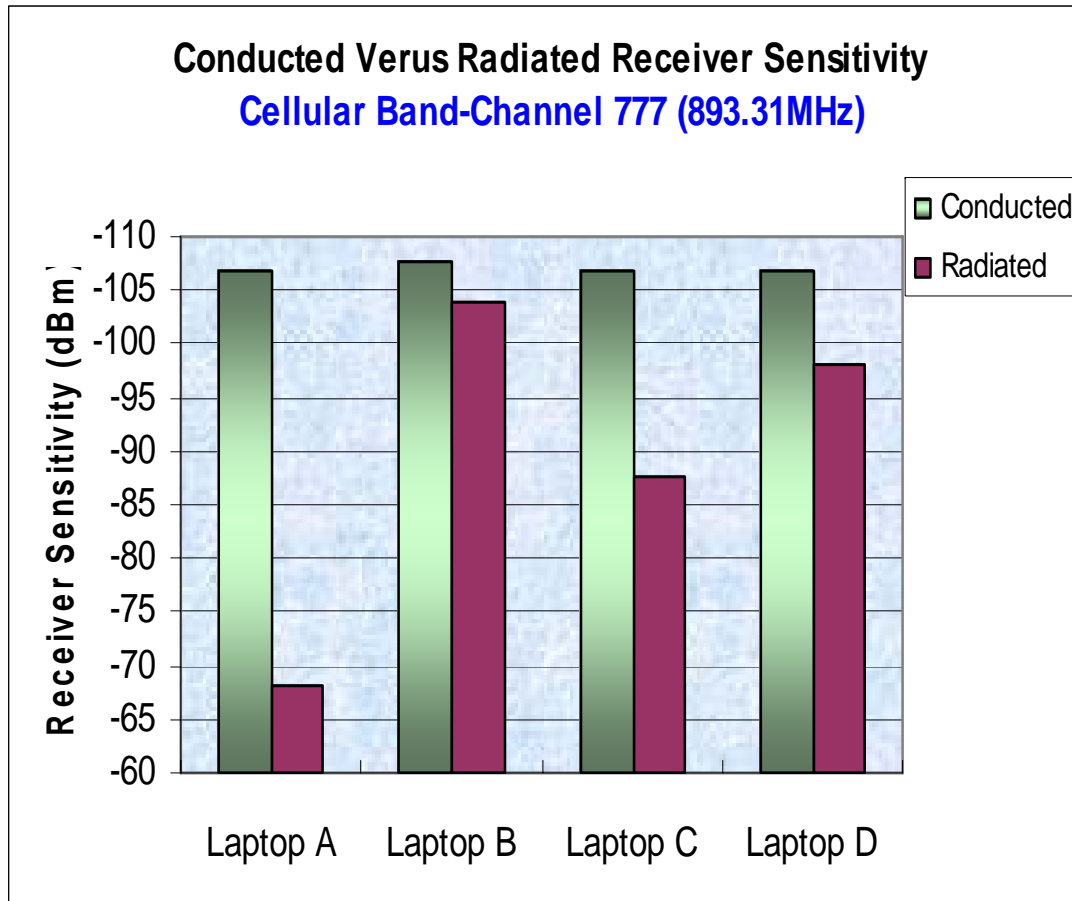
“We anticipate 16.4 million total units will ship in 2011. By that time, embedded modems as a percentage of shipments will have grown from 20% to 60%.” - *Strategy Analytics, January 2007*



Mini PCI



- The integration and coexistence of WWAN radios with other “noisy” electronics brings about new set of EMI considerations***

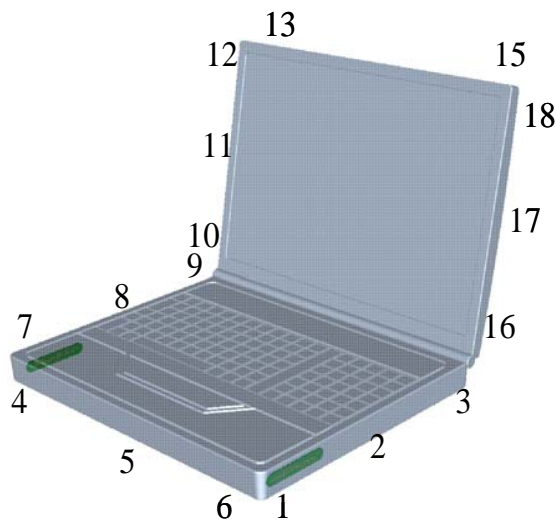


PC card in laptop.

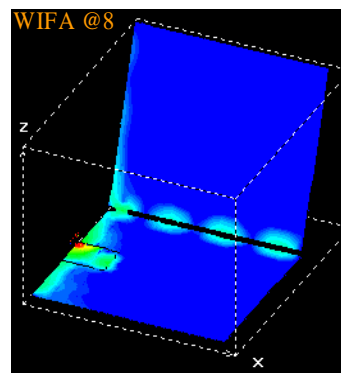
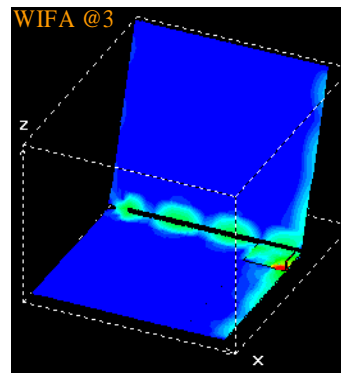
Entire laptop/card assembly tested as a single unit

Radiated tests are conducted with laptop streaming video to display

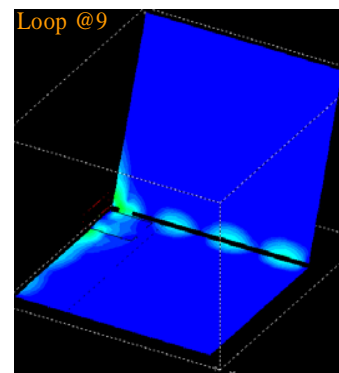
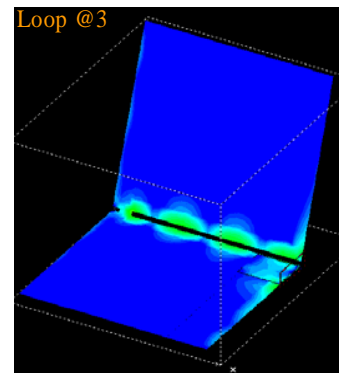
- ***Evaluated performance of various antenna types at various laptop locations***
 - Key antenna performance metrics evaluated for each location and type
- ***Prototypes built and integrated on a test laptop in the antenna range and in realistic network conditions***
 - Correlate measured antenna performance metrics to field performance parameters



Unbalanced Antennas



Balanced Antennas

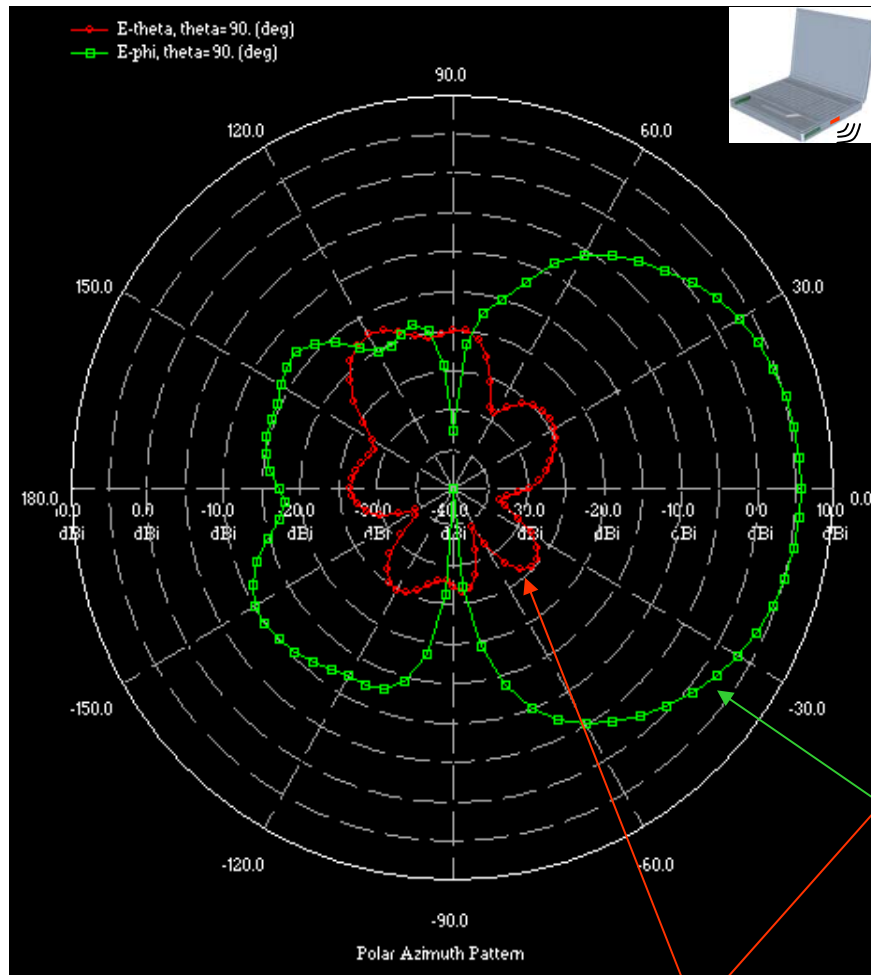


Body Interaction Evaluation

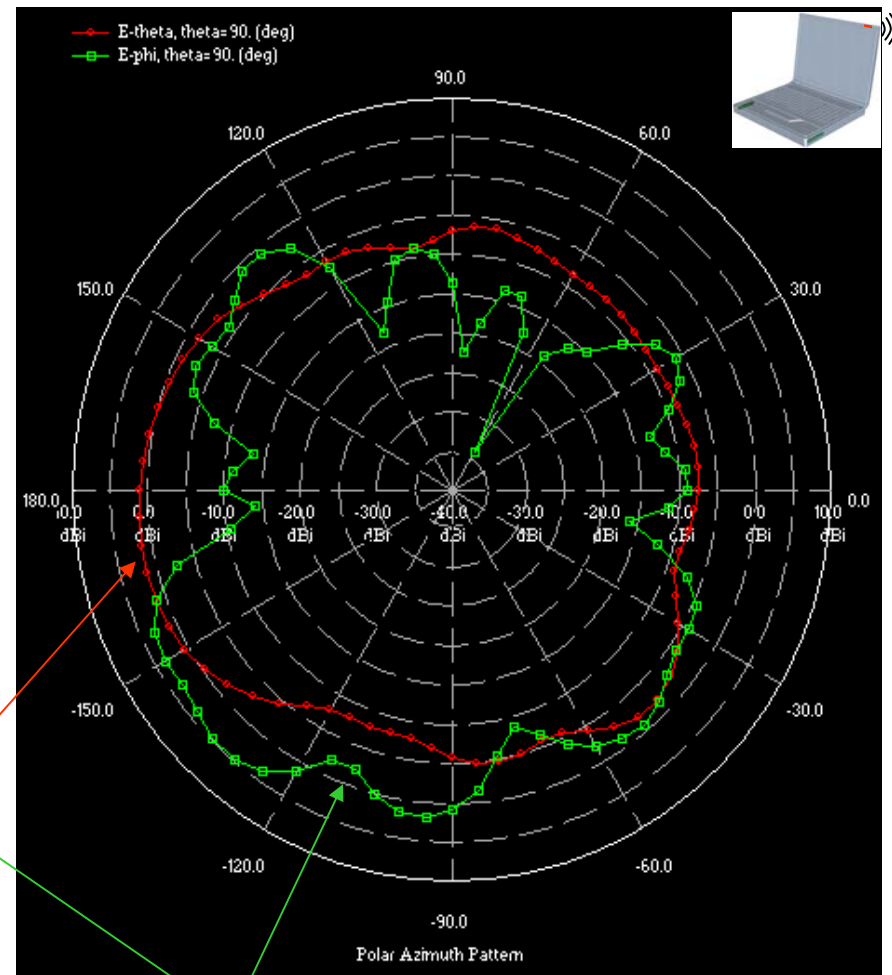


Pattern Performance vs. Antenna Location

Antenna embedded in lower Base



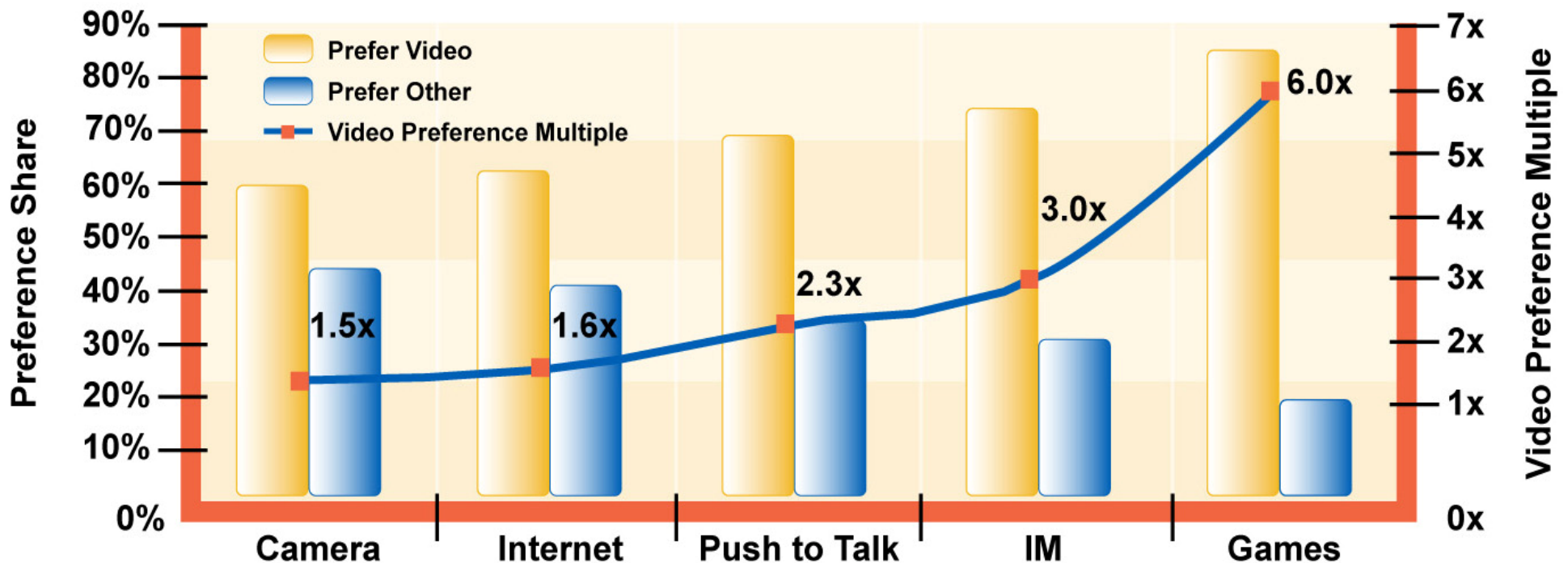
Antenna integrated in upper LCD



V-pol

H-pol

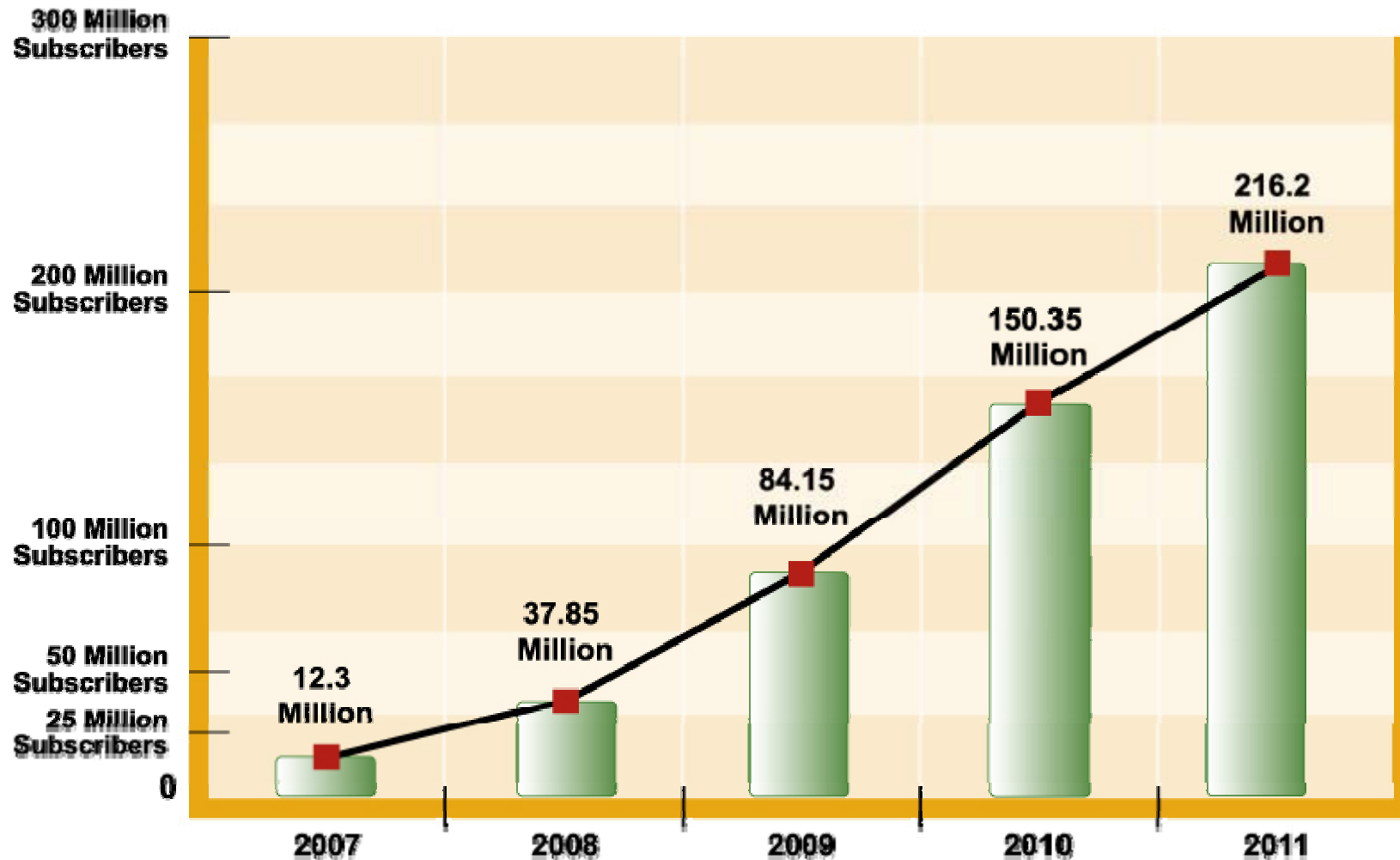
Consumer Preference Index: Video vs Alternate Features



- **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.
Compiled and combined by Robert Hale & Associates, 10/2006.*

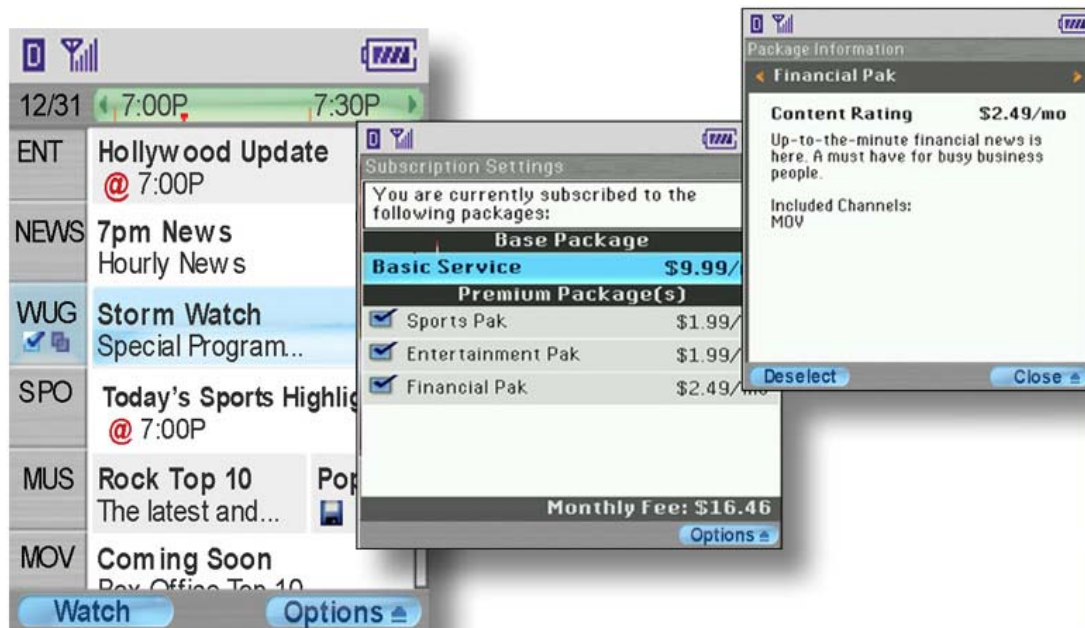
What MediaFLO Will Offer Customers

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



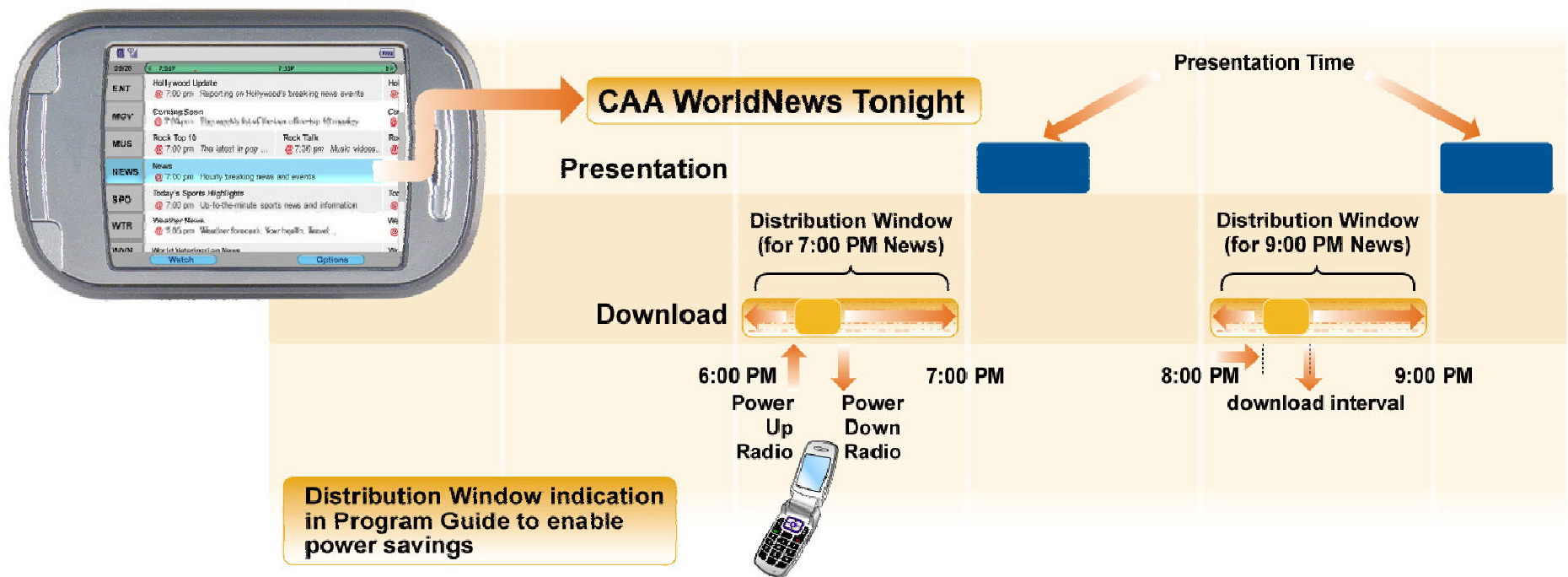
Subscription-Based Mobile Media Service

- *Service is based on a simple subscription model*
 - User receives keys for the subscribed services



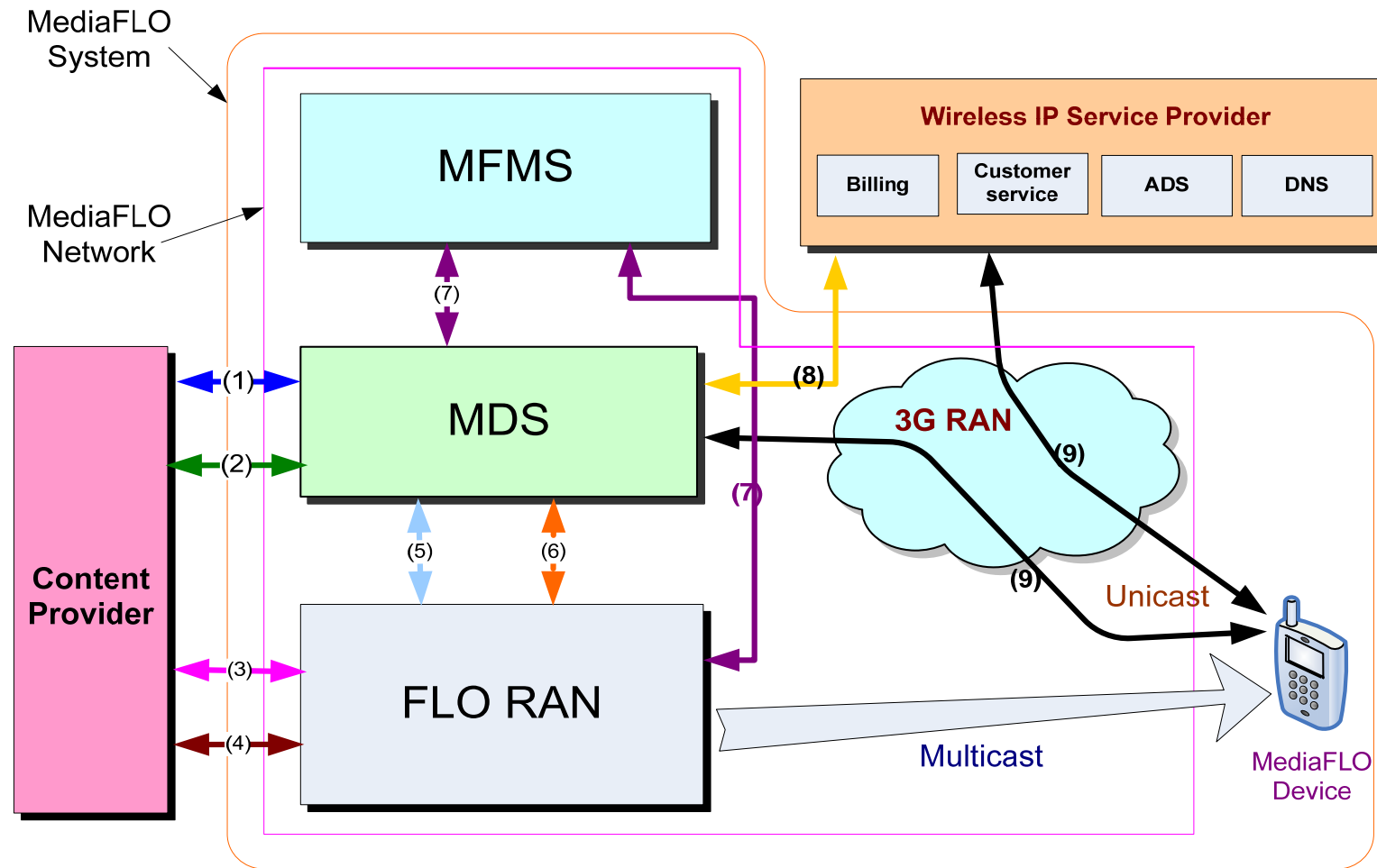
Clipcasting™ – Network Scheduled Media

- **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**



- **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, 1/2, and 2/3 are used

**For details:
see TIA-1099**



◄(1)► Non Real-Time CP-CS interface

◄(2)► Program guides, Presentation and Program records interfaces

◄(3)► IP Datacast CP-CS Interface

◄(4)► Real-Time CP-CS Interface

◄(5)► Content Encryption interface

◄(6)► Non-Real-time Bear and Signaling Interface

◄(7)► OA&M Interface

◄(8)► Billing Interface

◄(9)► Unicast

➡ Multicast

- *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