Evolution of Broadband Wireless Technologies
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Agenda

• Mobile Market Positioning

• What is 4G?

• 4G Technologies

• 4G Challenges
Nearly ~2 Billion More Than Any Other Computing or Consumer Electronics Device

Source: Wireless Intelligence, Instat, IDC, September 2007
Over 4 B Mobile Subscribers by 2012

Global & Emerging Economy Cumulative Subscribers

- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012

Source: Yankee Group, June 2008
670 M+ Current 3G Subscribers

Forecasted to Grow 1.6 B+ 3G Subs. by 2012
3G Handsets Forecast to Reach >55% of Total Handset Shipments by 2012

*2G includes cdmaOne, TDMA, GSM, EDGE, GPRS, iDen, PDC, PHS

Source: Average of Strategy Analytics (Jan 2008), InStat (Jul 2007), IDC (Jan 2008), Gartner (July 2007), Forward Concepts (Jul 2007), ABI (Dec 2007), Yankee Group (Dec 2007), WCIS+ (Feb 2008) and IMS (Oct 2007)
Broadband Connections Into the Next Decade

Forecasted Global Mobile Broadband Subscribers

HSPA Family includes HSDPA, HSUPA & HSPA+. EV-DO Family includes Rel. 0, Rev. A and Rev. B.
How did we get this far in just 25 years?

• **Relentless progress in silicon technology**
  
  • Higher integration, lower costs ($20 phones readily available in emerging markets), more capabilities.

• **Technical advances in air interfaces**
  
  • Higher efficiency for voice and data services, lower infrastructure capital costs

• **Sophisticated Signal Processing Algorithms**
  
  • Modulation, Coding, Detection, Synchronization etc.
Example of Advances in Air Interfaces

1 – Upper range for DL peak rates includes 64 QAM+2x2 MIMO or Dual Carrier 64-QAM
2 – 20 MHz, FDD, 64-QAM, 4x4 MIMO in DL and 16 QAM, 1 TX in UL. Peak rates expected to be scalable with bandwidth
What is on the horizon?

• After 3G there must be a 4G…

• Focus shifting from air interface to:
  • Network topologies
  • Services
  • Devices and Software
What is 4G?

The “Van Diagram” from IMT-Advanced

- **Enhancement**
- **Peak useful data rate (Mbit/s)**
- **Mobility**
  - High
  - Low
- **Interconnection**
  - Nomadic/local area access
  - Digital broadcast systems
- **New capabilities of systems beyond IMT-2000**
- **Dashed line indicates that the exact data rates associated with systems beyond IMT-2000 are not yet determined**

Source: ITU-R M.1645
The Road to 4G

- **1985**: AMPS, TACS
- **1995**: GSM, CDMA One
- **2000**: 2G
- **2005**: HSPA, 1xEV-DO, CDMA2000
- **2010**: 3G+, E 3G, LTE
- **2015**: IMT-Advanced 4G

- **Data Rate**:
  - <10kbps
  - <200kbps
  - 300k-10Mbps
  - <100Mbps
  - 100M-1Gbps

- **Mobility**:
  - Low
  - Middle
  - High
4G Wish List

• High Data Rates: 100 Mbps @250 km/h, 1 Gbps Nomadic
• Spectral Efficiency > 10bps/Hz
• Latency < 5 ms
• IP/Web based services
• Seamless connectivity and global roaming across multiple networks
• Smooth handoff across heterogeneous networks
• Guaranteed QoS for multimedia services
4G Technologies

• Air Interface
  • FDD and TDD
  • OFDMA?
• Throughput Enhancing Techniques
  • MIMO (Open and Closed Loop)
  • AMC (including space-time coding)
  • Dirty Paper Coding
  • Interference Cancellation, Joint Detection etc.
4G Technologies (Continued)

• Higher Layers
  • HARQ
  • Opportunistic Scheduling
  • Cross Layer Optimization

• 4G Networks
  • All IP Core
  • Cognitive
  • Multi-hop Relay
  • Micro, Pico and Femto Cells
## 3G and 4G Focus

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4G Challenge: Limited BW

BW = 100 MHz & 1 Gbps rate => 10bps/Hz => 1024 QAM

Tough on SISO Fading Channels!

Solution: MIMO

\[ N_R = N_T = 1 \]

\[ N_R = N_T = 4 \]

4G Challenge: High Tx Power

Tx Power proportional to Transmission Rate (for a given dist & $f_c$)

Assume 1Mbps @ 1km requires 1W Tx power

Then, 1Gbps @ 1km requires 1kW

Not Practical!

Distance < 100m at 1W Tx power (path loss exponent = 3)

=> New Network architectures
  - Multi-hop Relay
  - Micro, Pico and Femto Cells
Traditional Macro Networks

Data Rates Vary
Need uniform user experience

Increasing Demand for Data
Need economical ways to address future needs
Add Micro and Pico for Coverage and Capacity
Add Femtocells for User Deployment in Building

- Scalability
- Interference issues
- Fairness
- Operation & Management
- Restricted Femto access
- User deployed nodes

Mixed Networks Impose Challenges
Solutions for Improved Performance

- Plug and Play deployments
- Interference management
- Fairness among users
- Cognitive Self-organizing networks
Uplink Interference Solution: Backhaul to Supersite

- **Today**: Distributed processing at each cell. Backhaul carries decoded information bits.

- **Tomorrow (?)**: Centralized processing. Backhaul must carry a lot more!

Model collapses to a larger isolated cell with more Rx antennas
Uplink capacity for various strategies

- Power gain (More Hx Antennas)
- Inter Cell IC gain
- Intra Cell IC gain

Graph showing capacity [bits/sec/Hz] vs. Path Loss Exponent for different strategies:
- Matched Filter Distributed Processing
- Intra-Cell IC
- Inter-cell IC
- JD
Mobile Service Evolution

Services Evolution

Voice, Wallpaper, 2D Gaming, Location-Based Services, Mobile Commerce, 3D Gaming, Mobile TV, Health & Fitness

Text Messaging, Ringtones, MMS, Music & Video on Demand, Blogging, Social Networking, RSS Feeds & Tagging, Advertising & Recommend

Paul, How did the meeting go?
Send Options

Ringtones

Music & Video on Demand

Blogging
Social Networking

RSS Feeds & Tagging

Advertising & Recommend

Voicemail
Thank You