Hot Issues in Wireless Broadband Networking

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These slides are available on-line at:

http://www.cse.wustl.edu/~jain/talks/oe06.htm

1. Five wireless industry trends
2. Five wireless PHY innovations
3. Five wireless standards
4. Five wireless research trends

Five Wireless Industry Trends

1. Wireless industry is stronger than wireline.
   Particularly strong growth in developing countries.
2. 48% of global telco revenues coming from wireless
3. 26% of wireless revenues coming from data (vs voice)
4. Emerging new applications
   - Past: Voice, email, SMS, Ring tones
   - Present: Push, Gaming, Pictures, Instant Messaging
   - Future: Music, Video, Location, Remote monitoring, m-commerce
   - Long Term: Video telephony, remote enterprise applications, remote management, Multiparty collaboration
5. Wireless outselling wired home networking gear

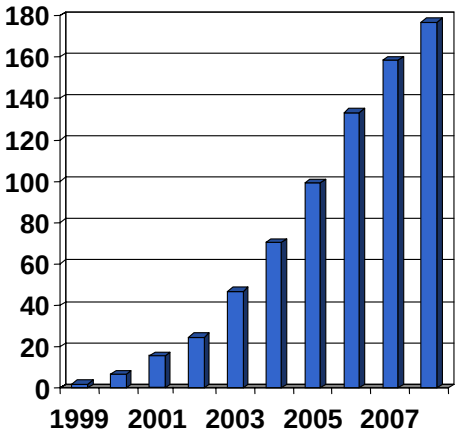
Telecom Revenue

	Revenue in Billions						
	2003	2004	2005	2006	2007	2008	Annual Growth
Video	0.2	0.3	.05	1.0	1.6	2.5	65.7%
Consumer Broadband	2.8	3.5	4.0	4.2	4.6	4.8	11.4%
Consumer long distance	20.7	18.2	16.0	13.6	11.3	9.2	-15.0%
Business local	26.3	26.7	26.4	26.1	25.8	25.5	-0.6%
Business long distance	26.1	24.5	23.0	21.3	19.7	18.2	-7.0%
Business data	44.8	45.6	46.6	47.1	46.8	45.4	0.3%
Consumer local	46.9	42.2	39.0	36.2	34.0	32.3	-7.25%
Wireless	91.5	108.7	119.2	132.8	144.5	153.6	10.9%
Total	260.7	271.5	277.0	285.0	291.3	294.9	2.5%

- Long distance is disappearing.
- Most of the revenues are going to be from wireless.
- Source: Instat/MDR (Business Week, Feb 28, 2005)

Wireless Data Connections

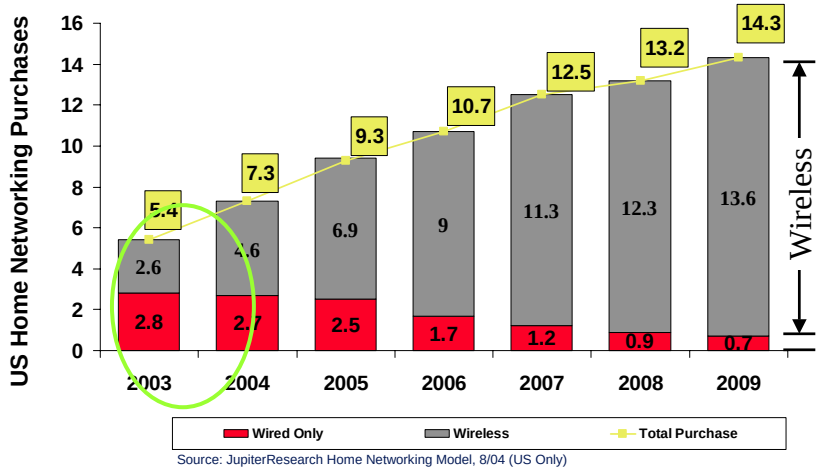
North American Wireless Data Connections (Millions)



Source: Gartner, "U.S. Wireless Data Market Update, 2004"

Home Networking Equipment Trends

(in millions)



Source: JupiterResearch Home Networking Model, 8/04 (US Only)

- Wireless outsold wired home networking gear for the first time in 2004

Cantenna

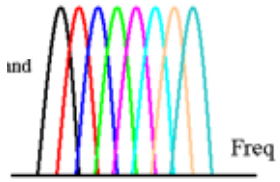
- 13,000 Free WiFi access nodes and growing
- 12db to 12db can-to-can shot can carry an 11Mbps link well over ten miles
- Ref: http://www.netscum.com/~clapp/wireless.html

Five Wireless PHY Innovations

1. Orthogonal Frequency Division Multiple Access (OFDMA)
2. Adaptive Antenna Systems (AAS)
3. Multiple Input Multiple Output (MIMO) Antennas
4. Space-Time Block Coding
5. Turbo Coding

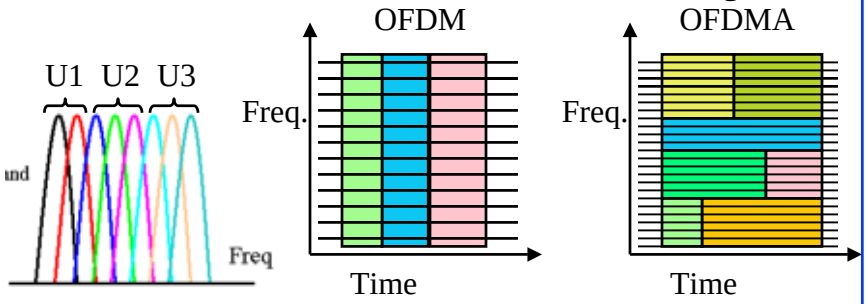
OFDM

- Orthogonal Frequency Division Multiplexing
- Ten 100 kHz channels are better than one 1 MHz Channel
  $\Rightarrow$ Multi-carrier modulation
- Available frequency band is divided into 256 or more sub-bands. Orthogonal $\Rightarrow$ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16, HDTV

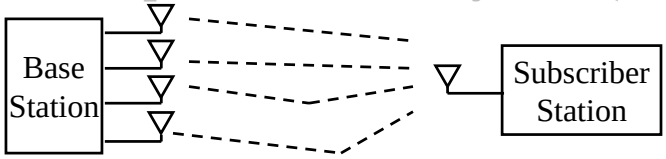


OFDMA

- Orthogonal Frequency Division Multiple Access
- A large number of subcarriers, e.g., 2048
- Each user has a subset of subcarriers
- OFDMA is a form of FDMA $\Rightarrow$ 2D Scheduling



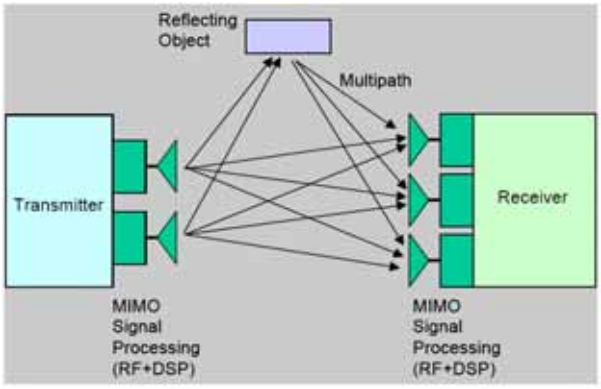
Adaptive Antenna System (AAS)



- Multiple antennas are used to transmit a subset of OFDM subcarriers each
- Example: 4 Antennas. 192 data subcarriers plus 8 pilot subcarriers are divided into 4 groups of 50 subcarriers each. Each of the four antennas transmits one group.
- Receivers perform channel estimation on each beam
- Receivers feedback the channel information to transmitter
- Transmitters adjust the beam forming accordingly
- IEEE 802.16 has MAC messages and burst format required for AAS. Allows mixing non-AAS and AAS subscribers.

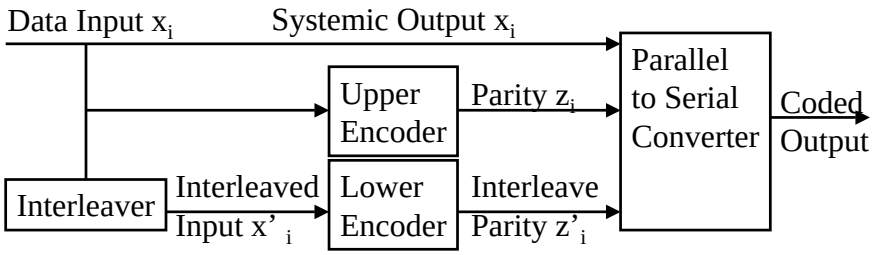
MIMO

- Multiple Input Multiple Output
- 54 Mbps/20 MHz = 2.7 bps/Hz,
  MIMO $\Rightarrow$ 108 Mbps or 5.4 bps/Hz



2x3

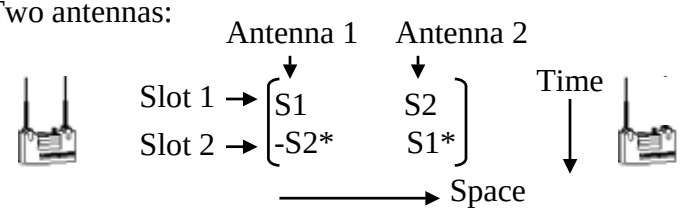
Turbo Codes



- Normal FEC codes: 3dB below the Shannon limit
- Turbo Codes: 0.5dB below Shannon limit
  Developed by French coding theorists in 1993
- Use two coders with an interleaver
- Interleaver rearranges bits in a prescribed but irregular manner
- 3rd Generation cellular networks use turbo codes

Space Time Block Codes (STBC)

- Invented 1998 by Vahid Tarokh.
- Transmit multiple redundant copies of the data from multiple antennas
- Precisely coordinate distribution of symbols in space and time.
- Receiver combines multiple copies of the received signals optimally to overcome multipath.
- Example: Two antennas:



S1* is complex conjugate of S1 ⇒ columns are orthogonal

Five Wireless Standard Technologies

1. Enhanced Security: 802.11i
   [Wired Equivalent Privacy (WEP) to
   Wireless Protected Access 2 (WPA2)]
2. Enhanced QoS: 802.11e
   Enhanced Distributed Coordination Function (EDCF) ⇒ Voice and Video over wireless
3. 802.11n
4. WiMAX
5. Ultra wideband

IEEE 802.11n

- 802.11n = Next Generation of 802.11
- At least 100 Mbps at MAC user layer
  ⇒ 200+ Mbps at PHY ⇒ 4x to 5x faster than 11a/g
  (802.11a/g have 54 Mbps over the air and 25 Mbps to user)
- Pre-11n products already available
- Task Group n (TGn) setup: Sept 2003
- Expected Completion: March 2007
- Uses multiple input multiple output antenna (MIMO)
- Main issue: Only one 20MHz channel or also allow two 20MHz channels bonded together
- Backwards compatible with 802.11 a, b, g
- One access point supports both standard WLAN and MIMO devices

IEEE 802.16: Key Features

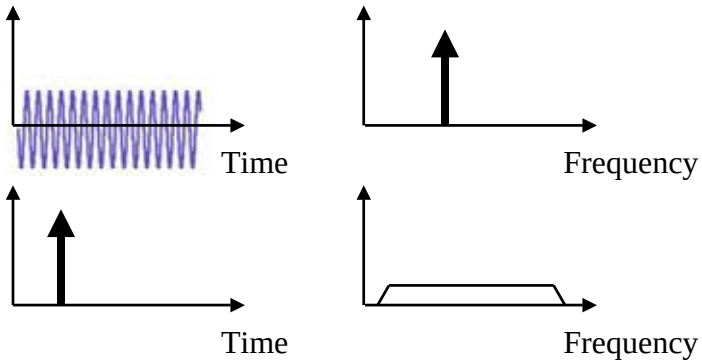
- Broadband Wireless Access
- Up to 50 km. Up to 70 Mbps.
- Data rate vs Distance trade off using adaptive modulation. 64QAM to BPSK
- Offers non-line of site (NLOS) operation
- 1.5 to 28 MHz channels
- Hundreds of simultaneous sessions per channel
- Delivers >1 Mbps per user
- Both Licensed and license-exempt spectrum
- QoS for voice, video, and T1/E1, continuous and bursty traffic
- Support Point-to-multipoint and Mesh network models

WiMAX

- A vendor organization for ensuring interoperability
- A WiMAX certified product will work with other WiMAX certified products
- Plugfests started November 2005
- 3rd WiMAX plug fest in France, March 2006.
- WiMAX forum lists certified base stations and subscriber stations from Aperto Networks, Redline Communications, and SEQUANS Communications
- WiBro = Korean implementation of WiMAX
- Competition: 3G, 802.11, ~~802.20~~

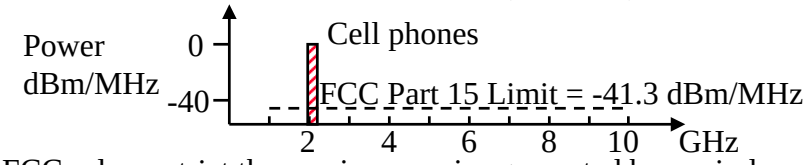
Cavemen of 2020

Ultra-Wideband



- An impulse in time domain results in a ultra wide spectrum in frequency domain and essentially looks like a white noise to other devices

Ultra-Wideband (UWB)



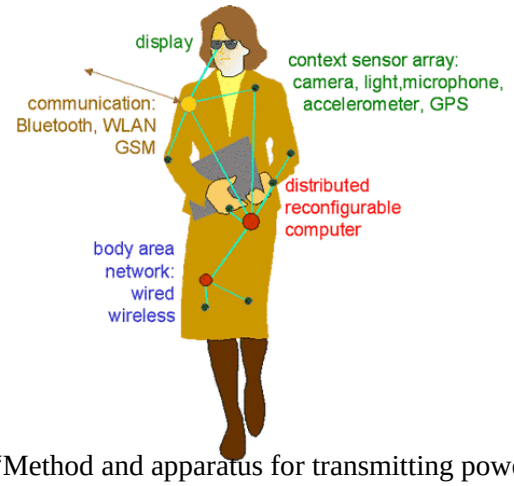
- FCC rules restrict the maximum noise generated by a wireless equipment (0 dBm = 1mW, -40 dBm = 0.1 μW)
- It is possible to generate very short (sub-nano sec) pulses that have spectrum below the allowed noise level
  ⇒ Possible to get Gbps using 10 GHz spectrum
- FCC approved UWB operation in 2002
- UWB will be used for high-speed over short distances
  ⇒ Wireless USB
- UWB can see through trees and underground (radar)
  ⇒ collision avoidance sensors, through-wall motion detection
- Position tracking: cm accuracies, Track high-value assets

Five Wireless Research Trends

1. NSF funded $40M for networking research over the past three years.
2. Three areas:
   - Software programmable networks
   - Sensor Networks
   - All other type of networking

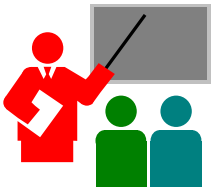
   Two Thirds of networking funding on wireless
3. Defense Networks are mostly wireless
4. Funding moving to Next Generation Networking Architecture (FIND) ⇒Mobility, Energy conservation ideas from wireless research can be generalized to wired networks
5. $300M+ for next generation test-bed (GENI). Currently a 20-node core network. Need to change to allow significant wireless component.

Body Area Networks (BANs)



- Microsoft, "Method and apparatus for transmitting power and data using the human body," US Patent 6,754,472, June 22, 2004.

Summary



1. Wireless industry is stronger than wireline.
   Particularly strong growth in developing countries.
2. OFDMA, AAS, MIMO, STBC, and Turbo codes have helped increase the rate
3. Significant improvement in security, QoS, throughput, and distance ⇒ 11n, WiMAX, UWB
4. Wireless networks will have a significant impact on next generation networking architectures.