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

Overview

- Five wireless industry trends
- Five wireless PHY innovations
- Five wireless standards
- Five wireless research trends

Five Wireless Industry Trends

- Wireless industry is stronger than wireline. Particularly strong growth in developing countries.
- 48% of global telco revenues coming from wireless
- 26% of wireless revenues coming from data (vs voice)
- 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
- Wireless outselling wired home networking gear

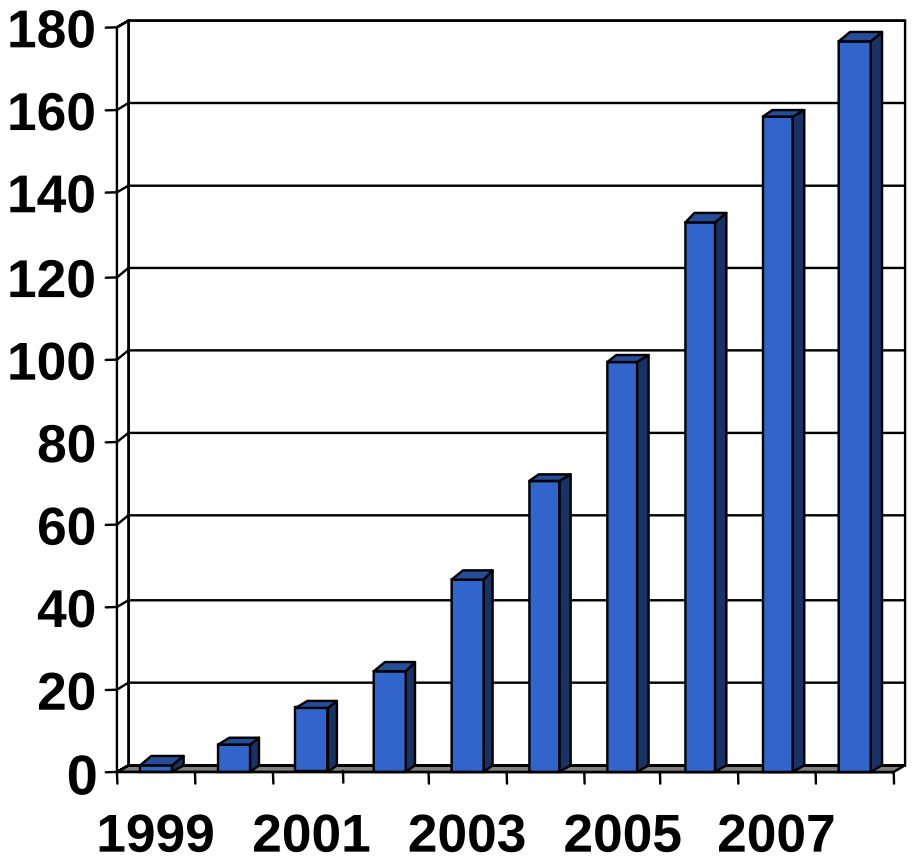
Telecom Revenue

	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)

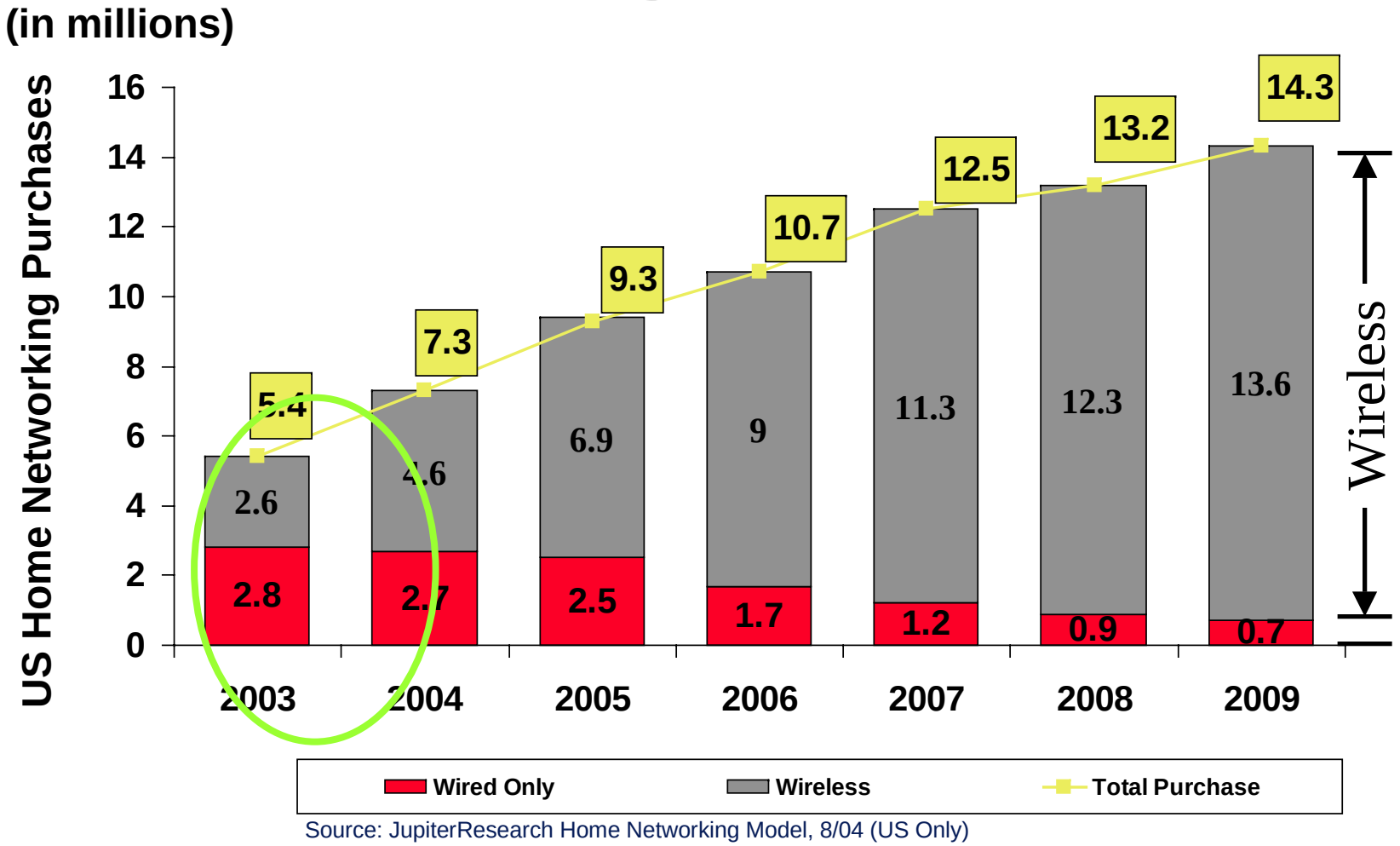
Wireless Data Connections

North American Wireless Data Connections (Millions)



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

Home Networking Equipment Trends



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

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

Cantenna

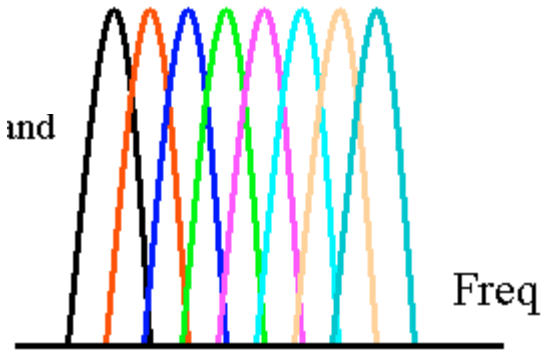
- 13,000 Free WiFi access nodes and growing
- 12db to 12db can-to-can shot can carry an 11Mbps link well over ten miles
- Ref: http://www.netscum.com/~clapp/wireless.html

Five Wireless PHY Innovations

- Orthogonal Frequency Division Multiple Access (OFDMA)
- Adaptive Antenna Systems (AAS)
- Multiple Input Multiple Output (MIMO) Antennas
- Space-Time Block Coding
- Turbo Coding

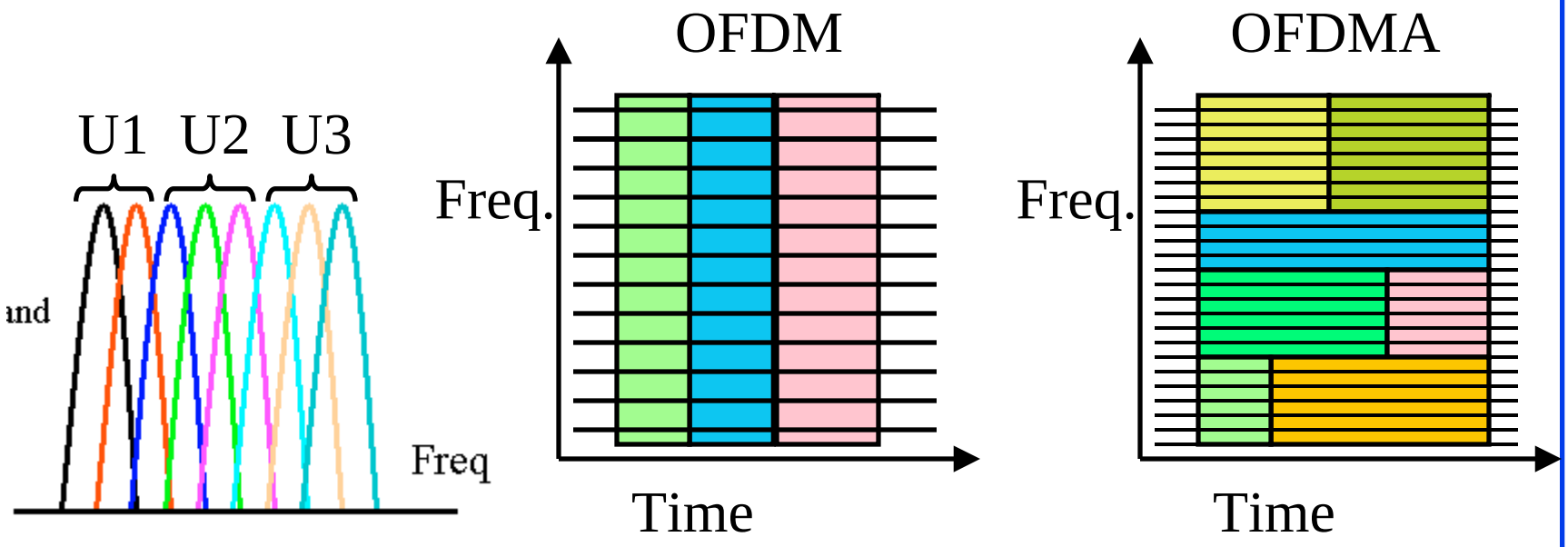
OFDM

- 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

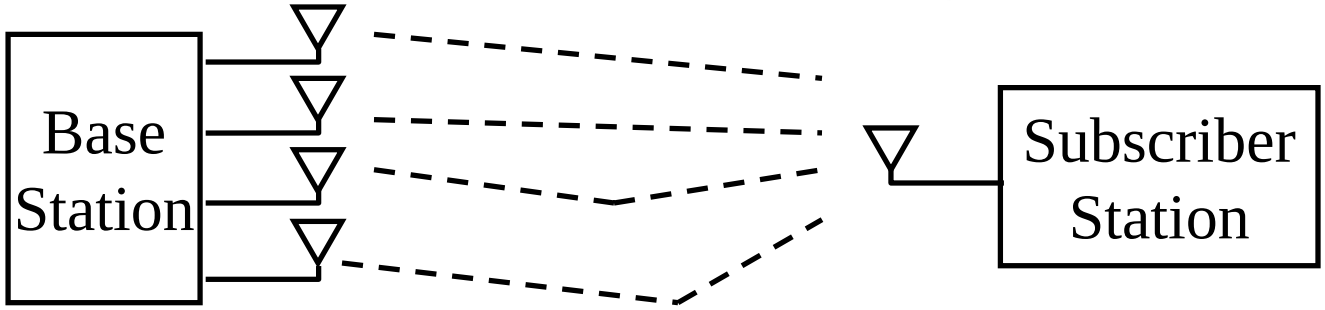


OFDMA

- 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 ⇒ 2D Scheduling



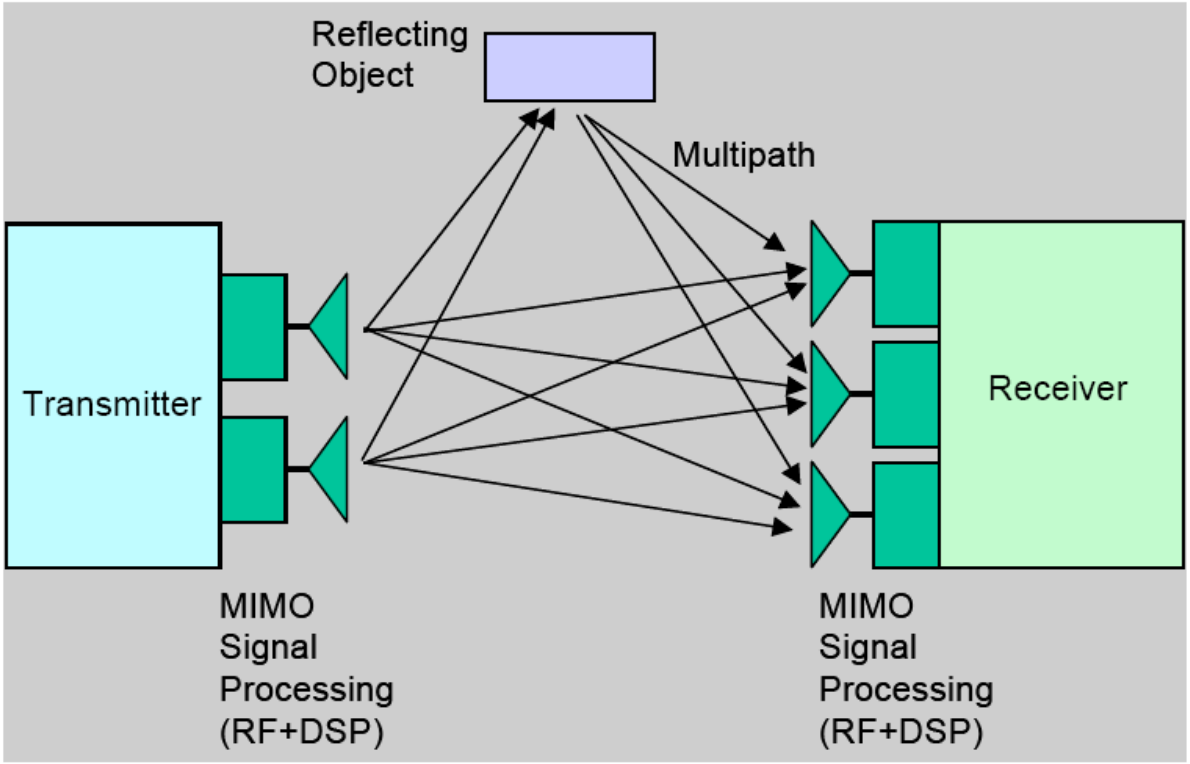
Adaptive Antenna System (AAS)



- 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.

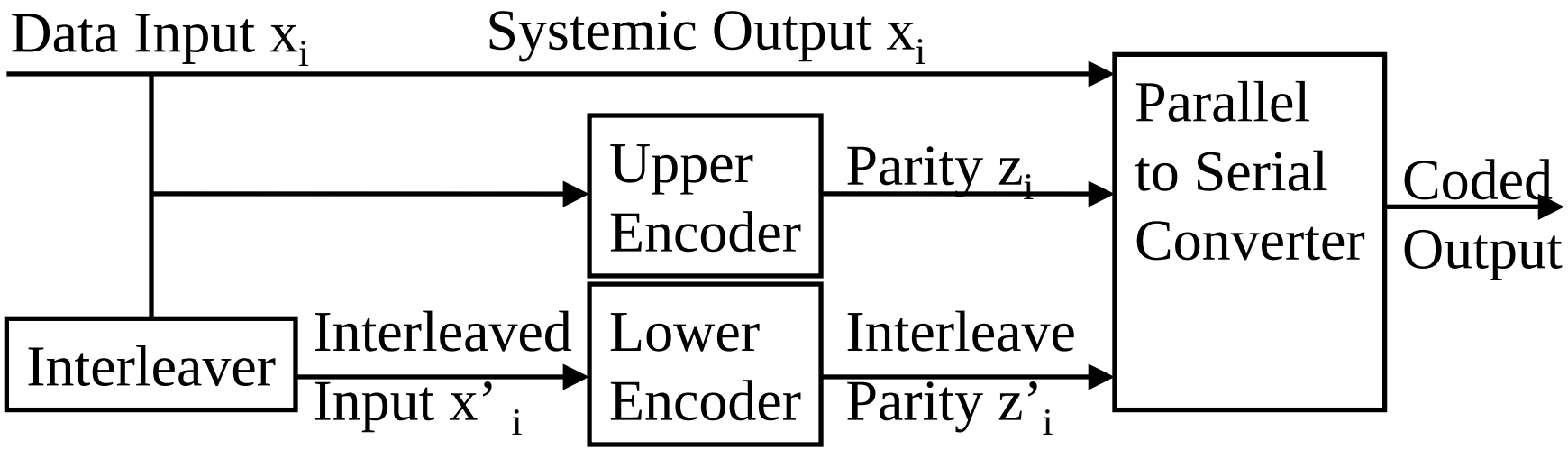
MIMO

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



2x3

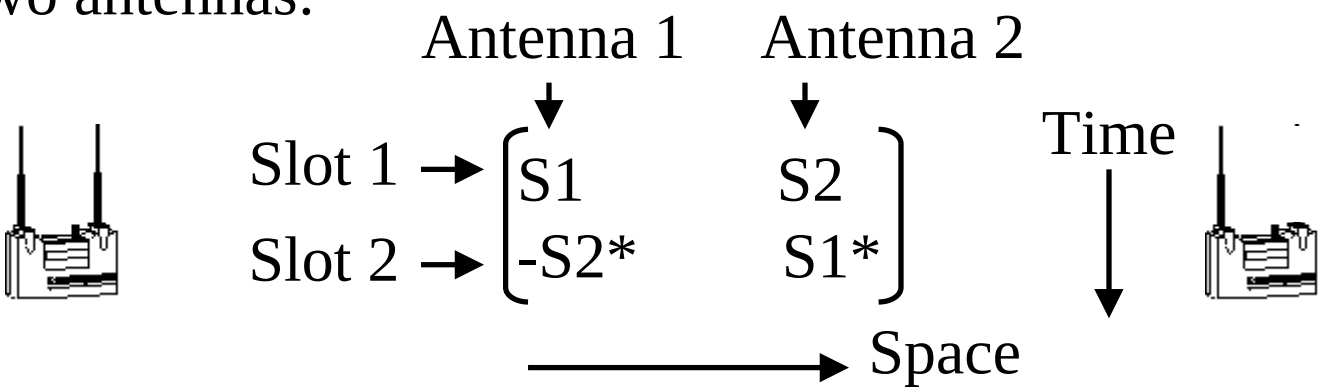
Turbo Codes



- 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

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

IEEE 802.11n

- 802.11n = Next Generation of 802.11
- At least 100 Mbps at MAC user layer
  $\Rightarrow$ 200+ Mbps at PHY $\Rightarrow$ 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

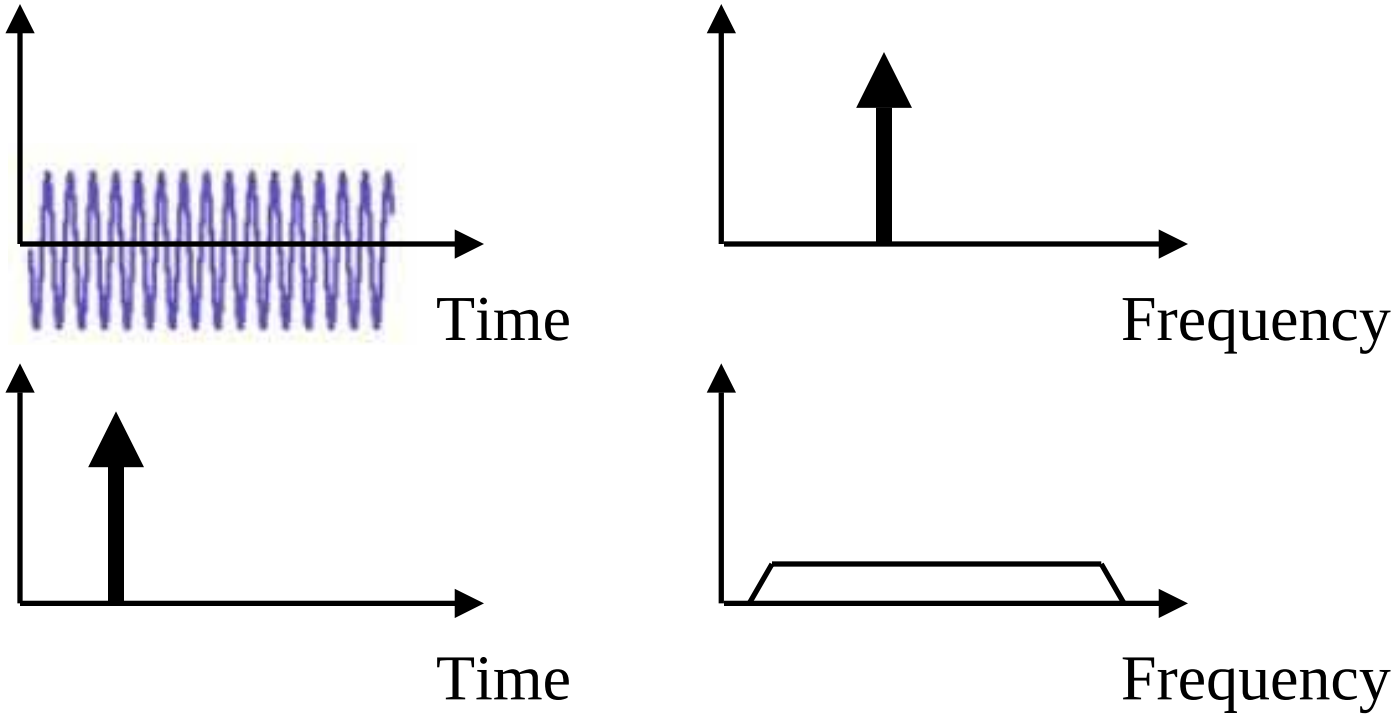
- Broadband Wireless Access
- Up to 50 km. Up to 70 Mbps.
- Data rate vs Distance trade off using adaptive modulation. 64QAM to BPSK
- Offers non-line of site (NLOS) operation
- 1.5 to 28 MHz channels
- Hundreds of simultaneous sessions per channel
- Delivers >1 Mbps per user
- Both Licensed and license-exempt 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~~

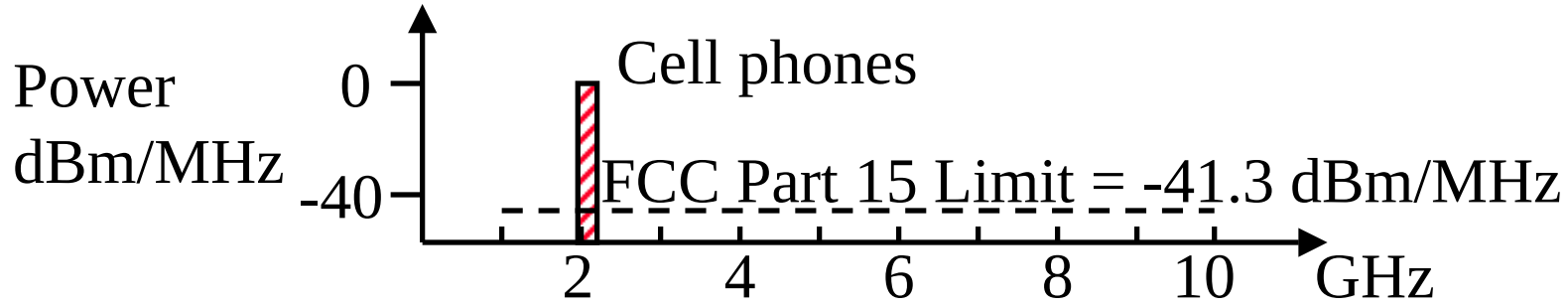
Cavemen of 2020

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)



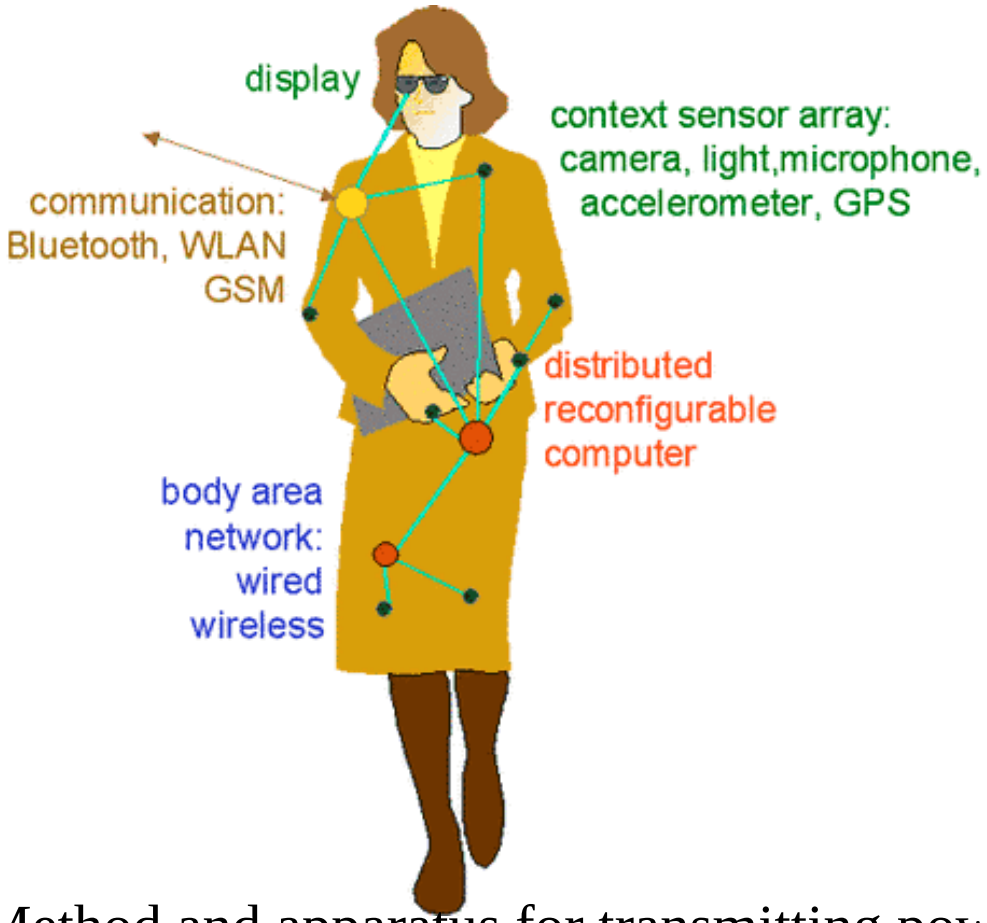
- FCC rules restrict the maximum noise generated by a wireless equipment (0 dBm = 1mW, -40 dBm = 0.1 μW)
- It is possible to generate very short (sub-nano sec) pulses that have spectrum below the allowed noise level
  ⇒ Possible to get Gbps using 10 GHz spectrum
- FCC approved UWB operation in 2002
- 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

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

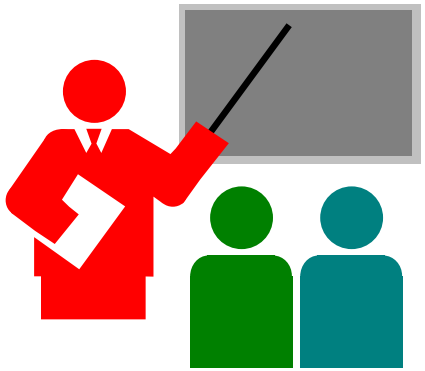
  Two Thirds of networking funding on wireless
- Defense Networks are mostly wireless
- Funding moving to Next Generation Networking Architecture (FIND) ⇒Mobility, Energy conservation ideas from wireless research can be generalized to wired networks
- $300M+ for next generation test-bed (GENI). Currently 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



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

Thank You!

Hvala

Grazie

Bedankt

Teşekkürler

Díky

Köszönettel

ขอบคุณ

شكراً

Ευχαριστώ

Merci

Gracias

Obrigado!

Vielen Dank

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