

# Wireless Networking: Trends and Issues



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These slides are available on-line at:

[http://www.cse.wustl.edu/~jain/talks/cs131\\_08.htm](http://www.cse.wustl.edu/~jain/talks/cs131_08.htm)

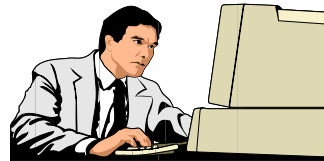


1. Recent Networking Developments
2. Wireless Networking Trends
3. Wireless Networking Challenges
4. Recent Wireless Technologies
5. Networking Courses at WUSTL

Goal: To get you interested in wireless networking research

## Stone Age to Networking Age

- ❑ Stone, iron, ..., automotive, electricity, telephone, jet plane, ..., networks caused a fundamental change in our life style



- ❑ No need to get out for
  - Office
  - Shopping
  - Entertainment
  - Education
- ❑ Virtual reality will satisfy your needs for
  - ❑ Games
  - ❑ Tourism
  - ❑ Sex

## Recent Networking Developments

1. Wireless (WiFi) is ubiquitous (Intel Centrino)
2. More Cell phones than POTS.  
Ratio projected to be 4-to-1 by 2012.
3. Wiring more expensive than equipment  
⇒ Wireless Access
4. Smart Cell phones w PDA, email, video, images  
⇒ Mobility

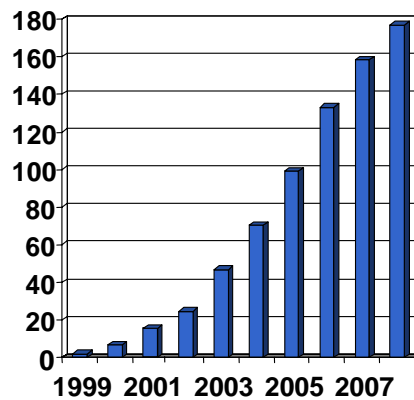
## Telecom Revenue

|                        | Revenue in Billions |       |       |       |       |       | Annual Growth |
|------------------------|---------------------|-------|-------|-------|-------|-------|---------------|
|                        | 2003                | 2004  | 2005  | 2006  | 2007  | 2008  |               |
| 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%          |

- ❑ 48% revenues are from wireless.
- ❑ 26% of revenue from data (vs. voice)
- ❑ Source: Instat/MDR (Business Week, Feb 28, 2005)

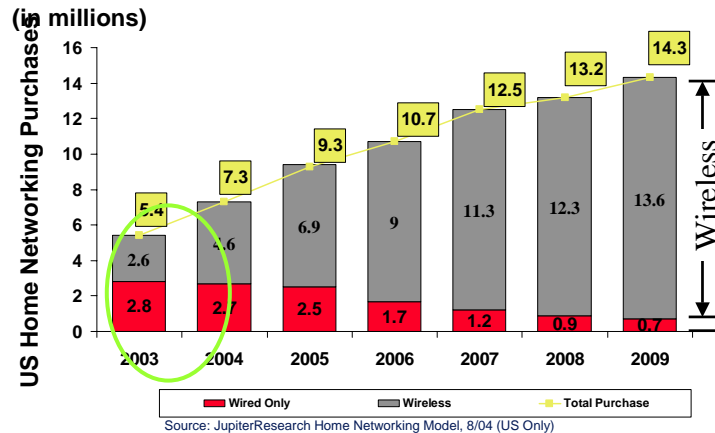
## Wireless Data Connections

**North American Wireless Data Connections (Millions)**



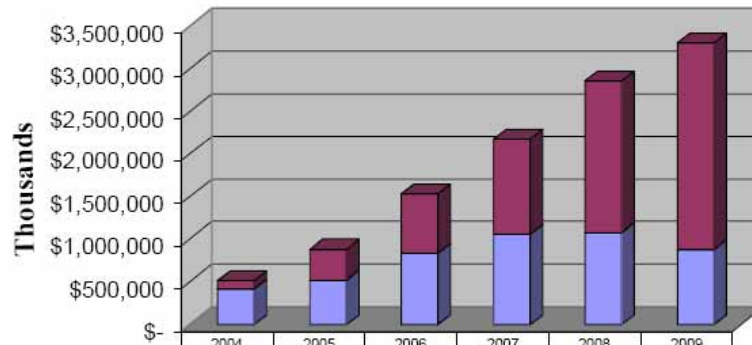
Source: Gartner, "U.S. Wireless Data Market Update, 2004"

## Home Networking Equipment Trends



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

## Personal Broadband: Fixed vs. Mobile

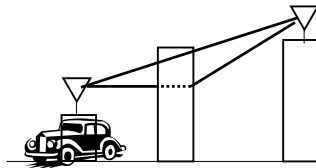


|                                    | 2004      | 2005      | 2006      | 2007        | 2008        | 2009        |
|------------------------------------|-----------|-----------|-----------|-------------|-------------|-------------|
| Portable/Mobile wireless equipment | \$100,655 | \$358,184 | \$699,616 | \$1,118,670 | \$1,776,591 | \$2,415,165 |
| Fixed wireless equipment           | \$414,125 | \$519,620 | \$829,612 | \$1,051,557 | \$1,072,812 | \$878,090   |

Source: Skylight Research

## Wireless Networking Challenges

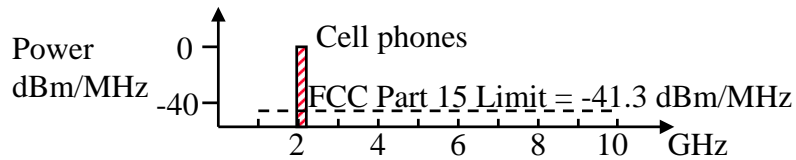
1. Propagation Issues: Shadows, Multipath
2. Interference  $\Rightarrow$  High loss rate, Variable Channel  
 $\Rightarrow$  Retransmissions and Cross-layer optimizations
3. Transmitters and receivers moving at high speed  
 $\Rightarrow$  Doppler Shift
4. Low power transmission  $\Rightarrow$  Limited reach  
100mW in WiFi base station vs. 100 kW TV tower
5. Unlicensed spectrum  $\Rightarrow$  Media Access Control
6. Limited spectrum  $\Rightarrow$  Limited data rate  
Original WiFi (1997) was 2 Mbps.  
New standards allow up to 200 Mbps
7. No physical boundary  $\Rightarrow$  Security
8. Mobility  $\Rightarrow$  Seamless handover



## Recent Wireless Technologies

- Ultra wide-band (UWB)
- Multiple-input Multiple-Output (MIMO)
- High-Speed Metro Wireless

## Ultra-Wideband (UWB)



- ❑ US Federal Communications Commission (FCC) rules restrict the maximum noise generated by a wireless equipment
- ❑ UWB uses signals below the allowed noise level but uses 500 MHz to 10 GHz of frequency spectrum  $\Rightarrow$  Ultra-wide band
- ❑ FCC approved UWB operation in 2002
  - Between 3.1GHz and 10.6GHz
  - More than 500 MHz bandwidth
- ❑ High-speed over short distances  $\Rightarrow$  Wireless USB

## Advantages of UWB

- ❑ Shares spectrum with other applications
- ❑ Large bandwidth
- ❑ Low probability of intercept and detection
- ❑ Resistance to jamming
- ❑ Superior penetration properties at low frequency spectrum
- ❑ Simple transceiver architecture. All digital. Low cost
- ❑ Very low energy consumption: Good Watts/Mbps
- ❑ Line of sight not required. Passes through walls.
- ❑ Sub-centimeter resolution allows precise motion detection.  
Track high-value assets

## UWB Products (Cont)



Belkin  
Wireless USB



Toshiba UWB  
Docking Station



IMEC  
UWB Chip



Cell phone with  
Infineon UWB  
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LeCroy UWB  
Protocol Analyzer  
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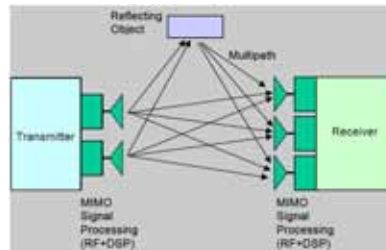


Haier's UWB-based  
HDTV Media Server  
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## 2. MIMO



- ❑ Multiple Input Multiple Output
- ❑ Simultaneous reception or transmission of multiple streams



2x3

## 802.11n High-Throughput WiFi

- ❑ Uses multiple input multiple output antenna (MIMO)
- ❑ Data rate and range are enhanced by using spatial multiplexing (N antenna pairs) plus antenna diversity
- ❑ Up to 200 Mbps
- ❑ Linksys, Belkin, D-Link, Netgear have pre-11 wireless routers



Belkin



D-Link



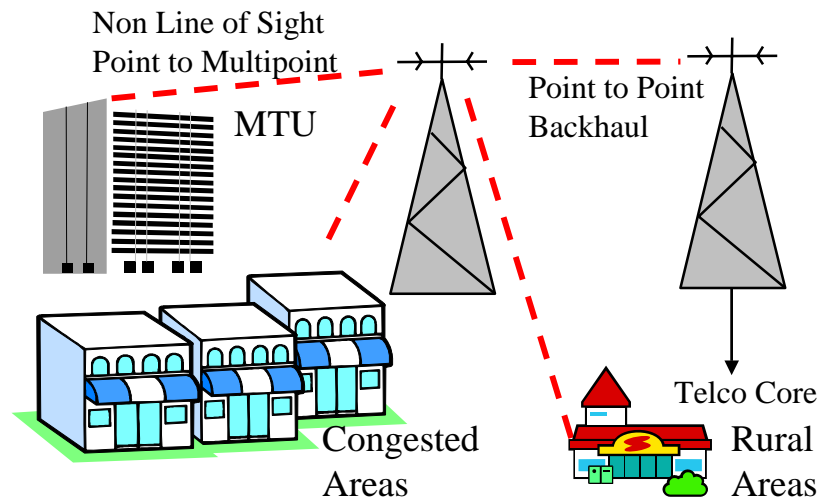
Linksys

## 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.netcum.com/~clapp/wireless.html>

## Metropolitan High-Speed Wireless: WiMAX



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## IEEE 802.16 (WiMAX): Key Features

- ❑ WiMAX = Wireless Interoperability for Microwave Access ⇒ Industry group for interoperability
- ❑ Up to 50 km or Up to 70 Mbps.
- ❑ Data rate vs Distance trade off w adaptive modulation.  
⇒ High rate near the tower.  
Lower as distance increases
- ❑ Offers non-line of site (NLOS) operation
- ❑ Hundreds of simultaneous sessions per channel
- ❑ Allows mobility
- ❑ Robust Security

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## Status of WiMAX

- ❑ WiBro service started in Korea in June 2006.
- ❑ Service available in Bangalore, India since 2007.
- ❑ Sprint-Nextel in 2.3/2.5 GHz with equipment supplied by Intel, Motorola, Samsung, Nokia, and LG.  
Initial deployment in Washington DC and Chicago (Sept 2008)
- ❑ More than 200 operators have announced plans for WiMAX
- ❑ About half are already trialing or have launched pre-WiMAX
- ❑ Two dozen networks in trial or deployed in APAC
- ❑ Intel has developed a multi-band WiMAX/WiFi chipset  
In laptops before the end of this year

## Sample WiMAX Subscriber Stations



Alvarion



Airspan



Axxcelera



Siemens



Aperto



Redline



SR Telecom



Telsima

## Cavemen of 2050



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## Networking Courses at WUSTL

1. CSE 473: Introduction To Computer Networks
2. CSE 471T: Communications Theory And Systems
3. CSE 521S: Wireless Sensor Networks
4. CSE 570A: Reinventing The Internet
5. CSE 571S: Network Security
6. CSE 572S: Signaling And Control In Communication Networks
7. CSE 573S: Protocols For Computer Networks
8. **CSE 574S: Advanced Topics In Networking (Wireless Networks)**
9. CSE 577M: Design And Analysis Of Switching Systems
10. CSE 578A: Multimedia Computing And Networking
11. CSE 7703: Research Seminar On Networking

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## Overall Summary



1. Wireless is the major source of carrier revenue  
⇒ Significant growth in Wireless networking
2. UWB uses a wide spectrum by keeping the signal level below the allowed noise floor
3. MIMO uses multiple antennas for high throughput  
Used in high-throughput WiFi
4. WiMAX with metro-wide wireless access is here
5. Working on gigabit wireless technologies

## References

- Audio/Video recordings and podcasts of several networking classes are available:
  - CSE 473: Introduction to Computer Networks,  
<http://www.cse.wustl.edu/~jain/cse473-05/index.html>
  - CSE 571S: Network Security,  
<http://www.cse.wustl.edu/~jain/cse571-07/index.html>
  - CSE 574S: Wireless Networks,  
<http://www.cse.wustl.edu/~jain/cse574-08/index.html>