Introduction to Computer Networking: Trends and Issues

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Audio/Video Recordings of this talk are available on-line at:

http://www.cse.wustl.edu/~jain/talks/iucee11.htm

Overview

1. Why study Computer Networking?

2. What are the key challenging research topics?

3. What is our group working on?

4. Courses for further information

Goal: This talk is designed to introduce undergraduate students to Computer networking, wireless, and network security research

Why Study Computer Networking?

❑ Networking is the "plumbing" of computing

❑ Almost all areas of computing are network-based.

  ➢ Distributed computing

  ➢ Distributed databases

  ➢ Distributed storage

❑ Fast growing field

❑ Job Opportunities: Google, Facebook, eBay, Microsoft, Cisco, HP, Intel, …

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
  ❑ Socialization

Current Issues in Networking

1. Network Security
2. Mobile Networking
3. Wireless Networking
4. Energy Efficient Networking
5. Multimedia Networking
6. Datacenter Networking
7. Internet Routing

Note: These topics are based on current activity in industry groups like Internet Engineering Task Force (IETF), Internet Research Task Force (IRTF), and Institution of Electrical and Electronic Engineering (IEEE)

1. Network Security

❑ No authentication:

➢ DNS attack: All YouTube traffic went to a black hole in Pakistan [Domain Name System (DNS) is used to convert names like www.youtube.com to Internet Protocol (IP) Addresses, e.g., 128.23.45.56]

❑ Phishing: Enter personal information on fake websites

❑ Spam

❑ Cyber warfare

Phishing

❑ Emails from banks and financial services leading to fake websites, e.g., http://www.bankofamerica.com may actually point to http://hackers.com

❑ Students in our Network Security course setup fake "free public wireless" service. Can grab passwords.

Fake Public Wireless

Real Public Wireless

SPAM

- 200 Billion messages/day 90-97% of all emails sent

- 81% of spam is about pharmaceutical drugs

- Cost businesses $100 Billion in 2007

- CAN-SPAM act of 2003

- Sent through Botnets of infected computers

Ref: http://en.wikipedia.org/wiki/Email_spam

Cyber Warfare

❑ Nation States are penetrating other nations computers

❑ In 2009, US set up a cyber command

❑ UK, China, Russia, Israel, North Korea have similar centers

❑ Targets: Telecommunications, Transportations, Power Grid

❑ Pentagon spent more than $100 million in first half of
2009 in repairing damages
from cyber attacks.

In Nov 2010, hackers calling themselves "Indian Cyber Army" attacked Pakistani Websites. In Dec 2010, "Pakistan Cyber Army" attacked Indian Central Bureau of Intelligence.

Ref: http://en.wikipedia.org/wiki/Cyber_war

2. Mobile Networking

- ❑ Smart Phones (iPhone, Blackberry, Android Phones), Net books, Laptops
  ⇒ Mobile computers

- ❑ Mobility: Keep your networking session connected regardless of your location

- ❑ Mobile ≠ Wireless.
  Starting your download at office and continuing it at home is an example of wired mobility

- ❑ Cellular phone networks are designed for mobility but Internet protocol is not.

3. Wireless Networking

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. New Developments:
   - ➢ 4G: 1Gbps Metropolitan Area Networks (LTE-Advanced, WiMAX V2)
   - ➢ Vehicular Networking (802.11p)
   - ➢ Ad-hoc Wireless Networks
   - ➢ TV Band (700 MHz) networking
   - ➢ Audio/Video over Wi-Fi (802.11aa)
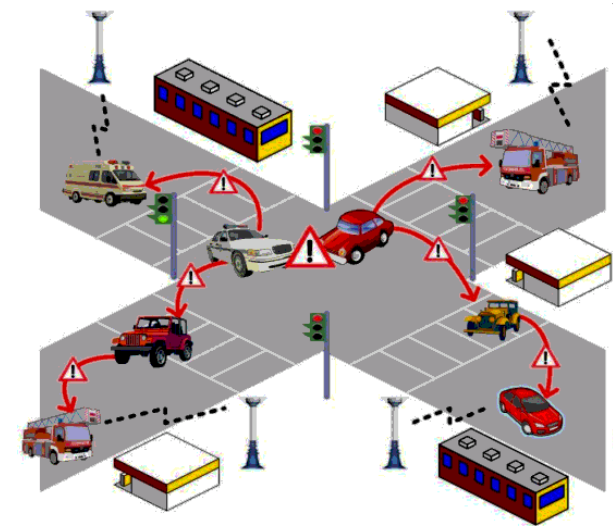
4. Energy Efficient Networking

❑ Original Internet design assumed all hosts are up all the time

❑ You cannot turn off your routers

❑ Computer Industry produces as much green house gases as the airlines industry

❑ One small computer server = one SUV with 15 miles/gallon

❑ Need to design protocols that allow nodes to be off

❑ Energy Efficient Ethernet:

➤ Turns off most of circuits until a bit arrives

❑ Delay-Tolerant Networking: Routers store data if the next hop is down
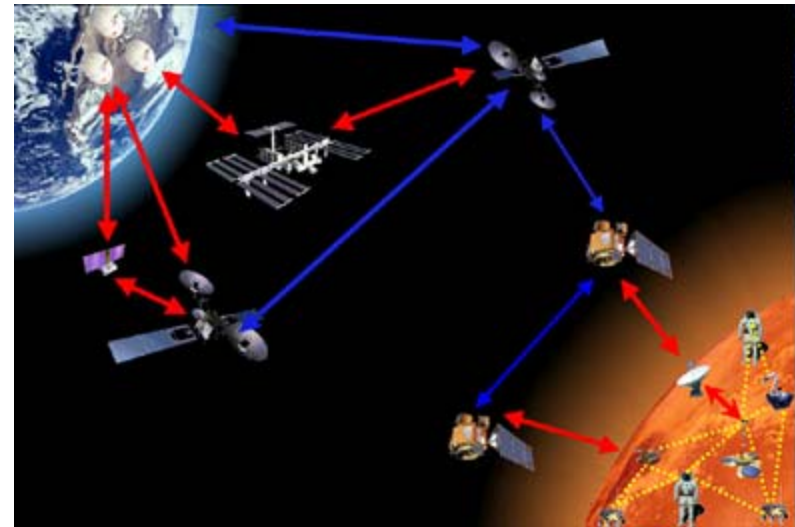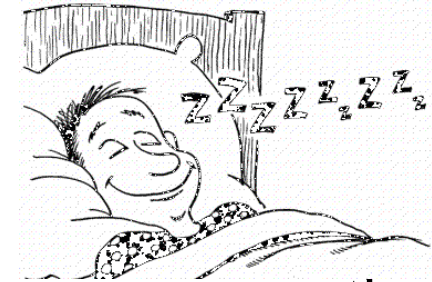
5. Multimedia Networking

- ❏ Trends:
  - ➢ Audio/Video over networks
  - ➢ Entertainment on cellular phones
  - ➢ Home Entertainment
  - ➢ Movies on Demand
  - ➢ YouTube
- ❏ Issues:
  - ➢ Timing and synchronization
  - ➢ Peer to peer streaming
 - ➢ Stream reservation
  - ➢ Media caching

6. Datacenter Networking

❑ Cloud Computing:
  ➢ Applications through Internet (Google Docs)
  ➢ Computing through Internet (Amazon EC3)
  ➢ Storage and backup through Internet

❑ Issues:
  ➢ Inter-Cloud Provider Networking: High-speed links on demand
  ➢ Policy, Security, QoS issues (Multi-organizational ownership)

❑ Data Center Networking: Ethernet optimized for data centers
  ➢ Congestion control at Multi-Gigabit Speeds
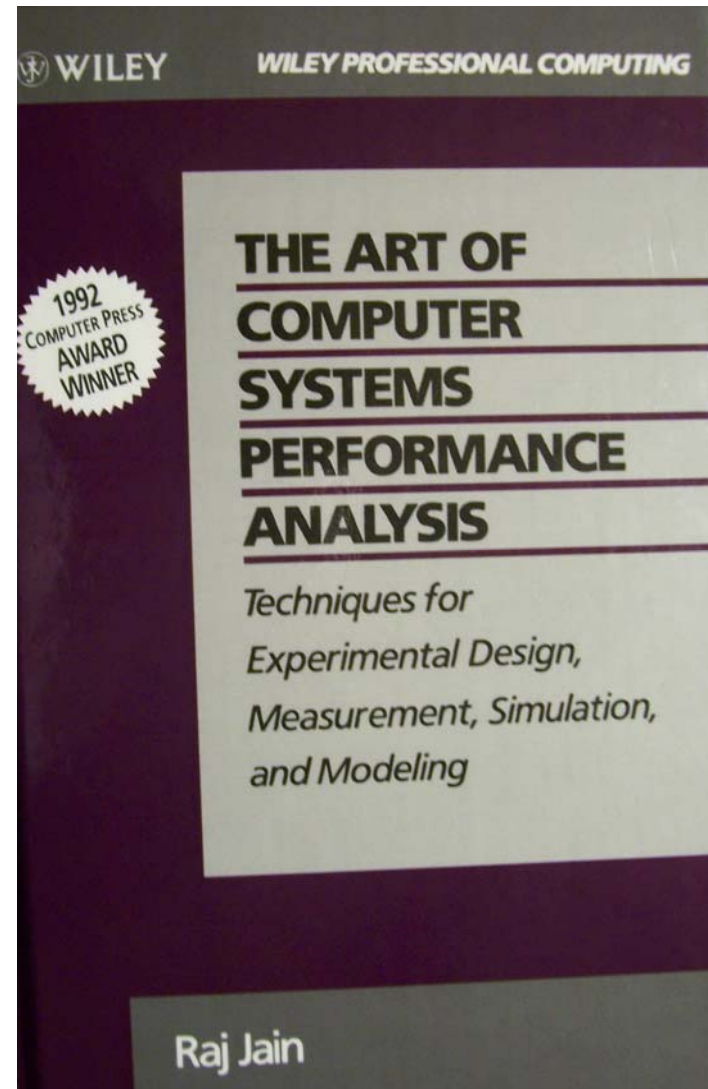 ➢ Micro-seconds transaction delays

7. Internet Routing

- ❑ Billions of nodes

- ❑ Large numbers of
  Internet Service
  Providers (ISPs)
  $\Rightarrow$ Scalability Issues

- ❑ Performance:
  Multipath routing

- ❑ Privacy issues
  $\Rightarrow$ Virtual overlay networks
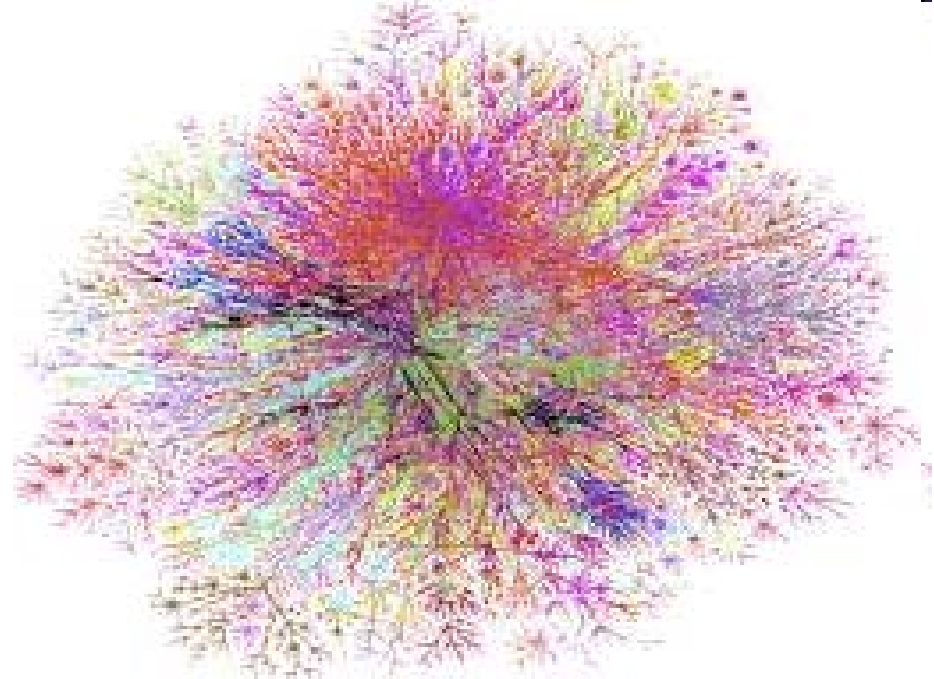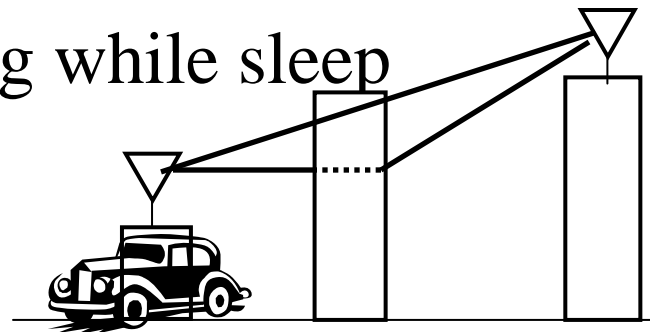
Our Areas of Research

1. Performance Analysis (Applies to all computer Systems: Networking, Databases, Algorithms, Architecture, Bio computing)

2. Networking Architecture

   1. Broadband Wireless

   2. Aeronautical Wireless
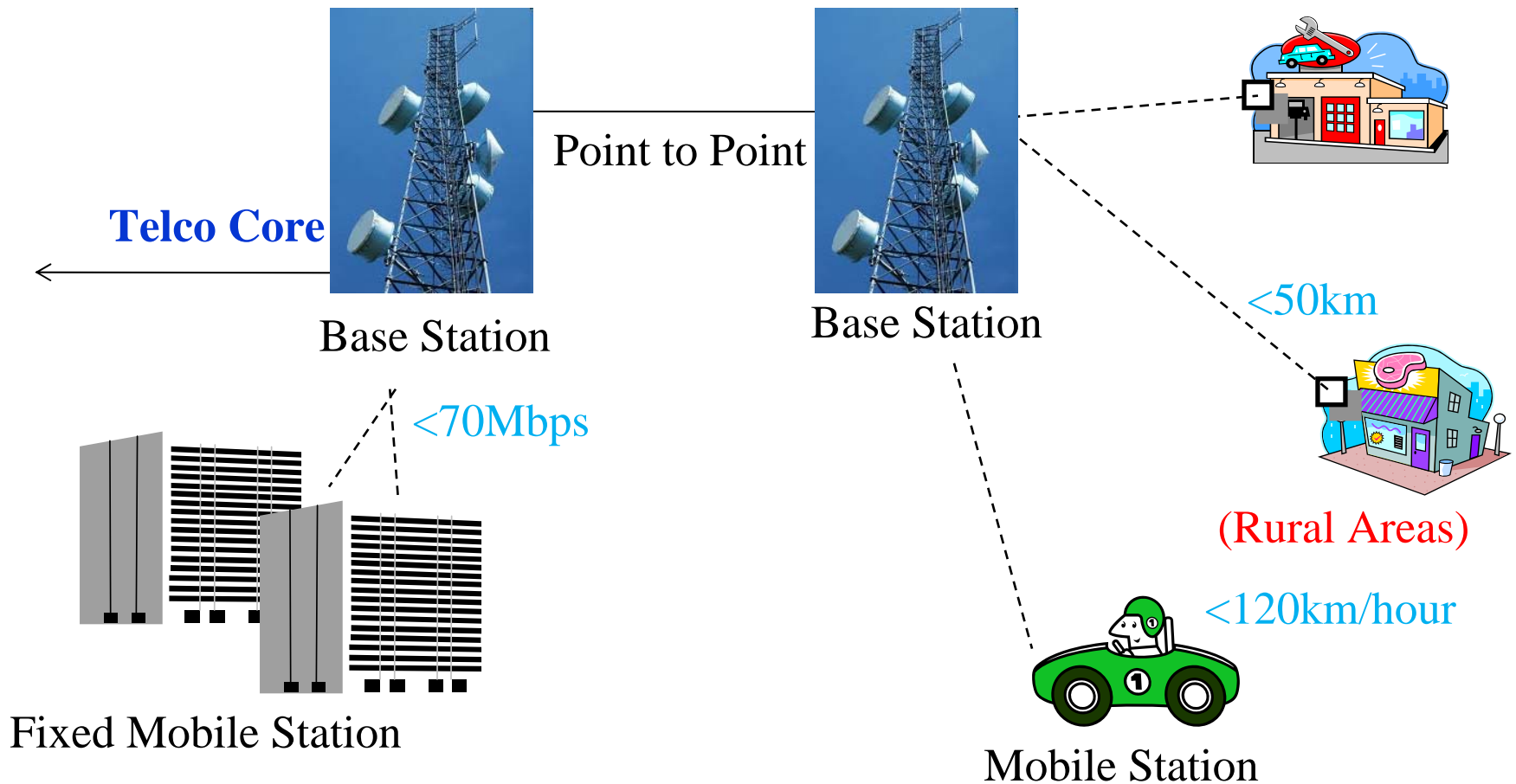
   3. Next Generation Internet

WILEY — WILEY PROFESSIONAL COMPUTING

1992 COMPUTER PRESS AWARD WINNER

THE ART OF COMPUTER SYSTEMS PERFORMANCE ANALYSIS

Techniques for Experimental Design, Measurement, Simulation, and Modeling

Raj Jain

Wireless Networking

Impact of Wireless on Networking:

1. Not tied to walls/infrastructure
   $\Rightarrow$ Ad-hoc networking

2. Error-prone $\Rightarrow$ Traffic Management

3. Frequent Disconnections
   $\Rightarrow$ Resource Management
   Quality of Service for multimedia

4. Battery operated
   $\Rightarrow$ Media access and networking while sleep
   $\Rightarrow$ Time synchronization

5. Broadcast $\Rightarrow$ Security

Metropolitan High-Speed Wireless

Best of WiFi + Cellular

Point to Point

Telco Core

Base Station

Base Station

<50km

<70Mbps

(Rural Areas)

<120km/hour

Fixed Mobile Station

Mobile Station

WiMAX and LTE: Key Features

❑ WiMAX = Wireless Interoperability for Microwave Access $\Rightarrow$ Industry group for interoperability

❑ Long Term Evolution (LTE)

❑ Up to 50 km <u>or</u> Up to 70 Mbps.

❑ Data rate vs Distance trade off w adaptive modulation.
$\Rightarrow$ High rate near the tower.
Lower as distance increases

❑ Both are 3.5G technologies

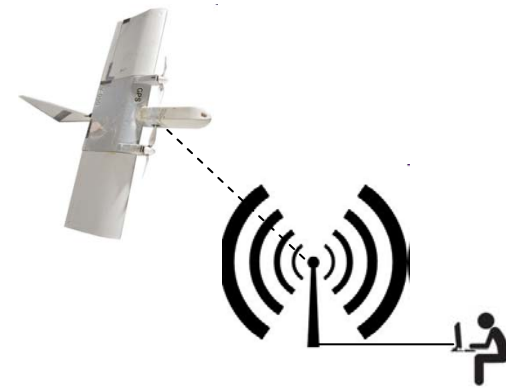❑ 1 Gb/s in the next generation $\Rightarrow$ 4G

Cavemen of 2050

Aeronautical Datalinks: Challenges

❑ Very long distances:
  ➢ Wi-Fi covers 100m. WiMAX covers 5km
  ➢ Aeronautical links need to cover 360 km
    ❑ Limited Power $\Rightarrow$ High bit error rate
❑ Very High Mobility:
  ➢ WiMAX is designed for 60 km/hr
  ➢ Aeronautical links need to cover 600 nm/hr (1080 km/hr)
❑ Unmanned Aircrafts: Border patrol, Drones

Next Generation Internet: Internet 3.0

- ❑ Internet 1.0: Before Commercialization
  - ➢ First twenty years (1969-1989)
  - ➢ No Security, Optimal routing
- ❑ Internet 2.0: After Commercialization
  - ➢ 1989-2009
  - ➢ Security, Policy based routing: ISP
- ❑ Internet 3.0:
  - ➢ The next 20 years
  - ➢ How would you design the networks, if you were to design it today
  - ➢ All leading universities all over the world are working on a "clean-slate" design
  - ➢ Internet 3.0 is the name of our clean-slate research program

Summary
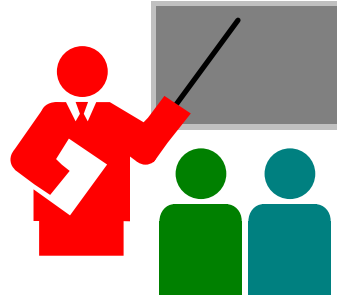
1. Computer networking is the backbone of all computing $\Rightarrow$ Cyber age

2. Key Issues: Security, Mobility, Energy, datacenters

3. Wireless is the major source of carrier revenue $\Rightarrow$ Significant growth in Wireless networking

4. Working on gigabit wireless technologies, Aeronautical wireless, and next generation Internet

References

- ❑ Audio/Video recordings and podcasts of several of our classes are available on-line for everyone:
  - ➢ CSE 473: Introduction to Computer Networks, http://www.cse.wustl.edu/~jain/cse473-10/index.html
  - ➢ CSE 571S: Network Security, http://www.cse.wustl.edu/~jain/cse571-09/index.html
  - ➢ CSE 574S: Wireless Networks, http://www.cse.wustl.edu/~jain/cse574-10/index.html
  - ➢ CSE 567: Computer Systems Analysis http://www.cse.wustl.edu/~jain/cse567-11/index.html